PB-217 572

SURVEY OF LITERATURE RELATING TO ATMOSPHERIC POLLENS AND HAY FEVER

John S. Wiley

Environmental Health Center
Cincinnati, Ohio

January 1950

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

V578 467

PB 217 572

SURVEY OF LITERATURE RELATING TO ATMOSPHERIC POLLENS AND HAY FEVER

Senior Sanitary Engineer John S. Wiley
Federal Security Agency, Public Health Service
Environmental Health Center
Cincinnati, Ohio

January, 1950

LIBRARY
ENVIRONMENTAL HEALTH CENTER
CINCINNATI, OHIO

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

SURVEY OF LITERATURE RELATING TO ATMOSPHERIC POLLENS AND HAY FEVER

Senior Sanitary Engineer John S. Wiley
Federal Security Agency, Public Health Service
Environmental Health Center
Cincinnati, Ohio

January, 1950

SURVEY OF LITERATURE RELATING TO ATMOSPHERIC POLLENS AND HAY FEVER

by Senior Sanitary Engineer John S. Wiley

Introduction

Preliminary to the inauguration of research work on atmospheric sampling for the determination of ragweed pollen concentrations, a cursory survey of the literature on pollens and hay fever was made. Even though this survey is far from complete it appears that it might serve as a source of information for those interested in this subject. Because of the similarity of sampling and counting procedures for the determination of air-borne pollens and bacteria, and in view of the trend toward additional research in bacterial air contamination, a number of the following references pertain largely to bacterial air sampling.

Abstracts have been prepared of a number of the references cited. As time permits it is proposed to abstract additional articles now listed and also to expand the list of references on the subjects of hay fever and atmospheric pollens and bacteria.

Historical

Pollen in the air has been noted since the time of the development of the microscope. However, there was no systematic investigation in the 19th or early 20th century. Such investigations as were made were dictated by the allergic reactions caused by the pollen. In 1866 Blackley made pollen counts in Manchester, England near ground level and also at some distance above ground by means of a kite. This was in advance of the pollen theory of hay fever. In 1875-6 the first pollen records in the United States were made by Dr. Marsh in Patterson, New Jersey and New York City.

During the period 1910-1916 clinical weapons against hay fever were developed in the form of desensitization treatments. Interest aroused by this work led to a recognition of causes of hay fever other than ragweed pollen. In 1916 the first daily counts in the United States were made in New Orleans by Sheppegrell, but pollen counts were not made in other cities of the United States until 1925.

Koessler and Durham showed the advantage of combined atmospheric and field methods of investigation. The first attempt to secure comparable pollen data on a nation-wide basis was initiated by Durham in 1928. The nation-wide data gave the initial counts for the year 1929 and were made in cooperation with the U. S. Weather Bureau. Since that time there have been yearly reports for most of the larger cities in the United States.

Pollen Sampling Methods

The purpose of making counts of pollen in the atmosphere is to determine the number of units of active allergen contained in a given volume of air. The difficulties in achieving the purpose are that there are many kinds of allergens differing in size, density and toxicity. In general a large pollen grain contains more allergen than a small one. Some methods of pollen determination are:

a. The "Gravity Method"

All of the early records were made after exposing a small glass slide coated with an adhesive consisting of petroleum jelly (or vaseline) out of doors. This method of collecting pollen samples is termed the "gravity method". Actually the microscope slide catches pollen grains in at least two ways: (1) by sedimentation from the air and (2) by impingement due to wind action (turbulent flow). Slides in the gravity method are exposed for 24 hour periods so that daily counts rather than instantaneous counts are obtained.

Sheppegrell in 1917 attempted to convert gravity counts into volumetric counts in terms of number of pollen grains per cu. yd. of air. He used Stokes' Law of velocity of sedimentation of a sphere in still air. Stokes' formula is as follows:

$$V = \frac{2\,gr^2\,(d_1 - d_2)}{9\,k}$$

where V is the velocity of sedimentation
g is the acceleration due to gravity, 980 cm/sec^2
r is the radius of the sphere.
d_1 and d_2 are the densities of the sphere and the air, respectively.
k is the coefficient of viscosity, which for air was taken as 0.00018.

However, Sheppegrell erroneously used the diameter instead of the radius of the pollen grains and thus was "off" 400%. Cocke first caught the error 20 years later in 1937 but he made additional errors. These were pointed out by Dahl in 1942. The formula for converting counts by the so-called gravity method to a volumetric count is as follows:

$$n = \frac{6.97\,N}{V\,t}$$

where n = no. grains/cu. yd.
V = Velocity from Stokes' Law
N = No. grains/cm^2 of slide
t = time in hours (usually 24)

All of the above investigators assumed the specific gravity of pollen to be 1.0 (the specific gravity of air is 0.0012046). Because of the relatively small density of air they disregarded the density factors in Stokes' Law, substituting 1.0 for d_1 minus d_2. Durham in 1943 ran experiments on the volume and weight of pollen grains and thus derived the specific gravity of common ragweed as 0.85 and southern ragweed as 0.50. These values were far different from the originally assumed specific gravity of 1.0 and therefore threw the prior computations off. Later (1946) Durham actually measured the rate of fall of pollen grains in still air inside a long iron tube. He

found that ragweed pollen fell faster than the theoretical velocity from Stokes' Law. (0.027 f.p.m. vs. 0.019 for tall ragweed; 0.029 f.p.m. vs. 0.022 for short ragweed).

Durham still realized that the gravity method did not depend entirely on the settling of pollen grains. He compared gravity counts with 2 volumetric samplers, the Hawes impinger and the Koitt filter. The volumetric samplers checked very well but the gravity slides did not. Thus, using his own density factor (common ragweed pollen = 0.55) he determined that the gravity counts should be multiplied by about 13 to convert them from the count per square centimeter to the count per cu. yd. of air. His tests showed factors from 1/2 to 7 times the factor 13.

In spite of the discrepancies in counts by the gravity method Durham proposed a standard method of gravity sampling, counting and volumetric interpretation of results (1946). A ratio of 3.6 (count per cu. yd. of air = 3.6 times the gravity count per sq. cm.) was proposed; but in calibrating Durham got from 1.1 to 7.0 as factors. Volz, using Durham's own calibration figures, indicated that the data showed considerable scatter but that the ratio from the line of best fit was 2.8 instead of 3.6. More recently Crawford determined the specific gravity of the pollen of common ragweed, Ambrosia elatior, by elutriation and permeameter methods. These two methods were reported to have checked with a specific gravity figure of 1.3, considerably higher than any previous estimates or determinations. Crawford then suggested a factor of 5.53 times the gravity slide count to give the count per cu. yd. of air.

b. Volumetric Methods

No standard volumetric sampling device has been recommended for pollen sampling. In addition to the Hawes impinger and the Koitt filter, Durham also used the Hill Dust Pump in calibrating other devices. The Wells air centrifuge has been mentioned by some but Cody et al indicated that the high air velocity caused some of the pollen to break up making an accurate pollen count impossible. Cody also reported that the Erdtman's Aerosol Collector was unsatisfactory because of the laborious and time-consuming analysis of the collection filter. Cody et al proposed a volumetric instrument for the concentration of pollen of the atmosphere. This embodies many of the plans of the apparatus developed by Dalla Valle and Hollaender for use in sampling the atmosphere for air-borne bacteria. A number of dust and fume samplers and bacterial samplers should be effective in collecting and concentrating the considerably larger ragweed pollen. These are the electrostatic dust and fume sampler, the standard Greenburg-Smith impinger, the midget impinger and the Luckiesh-Holladay-Taylor electrostatic bacterial air sampler. These instruments have apparently not been tested for pollen sampling except in the current study being conducted at the Environmental Health Center.

In 1947 Durham calibrated an air whip against the Hawes impinger. He proposed the use of the air whip for rough quantitative measurements of pollen in the field on an instantaneous or spot-testing basis.

REFERENCES

The following references with pertinent abstracts are listed according to subject matter. Several articles pertain to more than one of the subjects and may therefore be listed more than once.

1. IDENTIFICATION OF POLLEN GRAINS

Durham, Oren C. - Your Hay Fever, Bobbs - Merrill, Indianapolis, 1936

Erdtman, Gunnar - An Introduction to Pollen Analysis, Chronica Botanica Co., Waltham, Mass., 1943

Veldee, Milton - Specifications Recommended as Guides in the Collection and Preservation of Pollen, Ann. Allergy 6:56-60 Jan. - Feb., 1948

Werrick, T. J. - A Comparison of Cedar Oil and Other Materials in the Making of Slides of Atmospheric Pollen, J. Lab. & Clin. Med., 25:1086-90 (1940)

Wodehouse, R. P. - Pollen Grains, McGraw-Hill, NY, 1935

Wodehouse, R. P. - Atmospheric Pollen, Aerobiology, Pub. No. 17, Washington: Amer. Assoc. Advancement Science, 1942, pp 8-31

Abs. - This chapter is on identification of pollen grains. Many species have no visible differences, so need botanical survey, also reference collection. (Shake pollen to microscope slide, treat with 1 drop 95% alcohol. Just before complete evaporation add 1 drop melted basic fuchsin glycerine jelly, warm, put on cover glass, and press. Observe details @ 600 to 1200X). Rest consists of identification points and plates of all types of pollens. Ragweeds (Ambrosiae) are anemophilous, have only rudimentary spines. Common (Ambrosia elatior) (short) avg. d. 18.3μ (17.6-19.2), spines short conical, about 0.5μ high, 2.3-3.4μ apart. Giant (A. trifida) Avg. d 17.7μ (16.5-19.2), spines slightly larger, Avg. 3.4μ apart.

2. POLLEN SAMPLING METHODS

Cocke, E. C. - A Method for Determining Pollen Concentration of the Air, J. Allergy - 9:458-463 (1938)

Cody, B. J.; Kinney, W. F.; Kerstein, N. A. - Apparatus for Determining the Pollen Concentration of the Atmosphere, Research Department, Detroit Edison Co., Detroit (Oct. 6, 1941)

Abs. - Instrument was devised to ascertain pollen concentration per unit of air volume. Done by Detroit Edison Co. to evaluate influence of air conditioning on pollen density. "Gravity" method does not

Abs. (Cont'd.) measure amount of air sampled. Erdtman's Aerosol Collector requires too much labor and time to analyze the collection filter. The Wells' Centrifuge claimed to break up pollen due to high air velocities. The new device has several features of that used by Dalla Valle and Hollaender in air-borne bacterial sampling.

Instrument consists of: cylindrical metal casing with metal outlet and neck which accommodates a one-hole rubber stopper. In the stopper is inserted a long straight glass tube to which is attached an integral glass exit funnel centered over a microscope collection slide at the bottom. Another integral glass shielding funnel extends over the exit funnel within the metal casing and covers almost the entire inner area of a Petri dish (Authors later state the necessity of shielding funnel is doubtful). Vertical clearance of 1/8-in. is allowed between edges of exit funnel and microscope slide. Copper wire connects from glass tube to metal outlet tube to prevent electrical potential difference. This entire top assembly fits a recess in bottom of cork-gasketed metal base. Fitted sheeting is placed in bottom of Petri dish with hole cut to facilitate proper placing of microscope slide. Slide is coated with glycerine jelly. Air is drawn through instrument by vacuum pump and gas meter is inserted in outlet line to measure air flow. Air goes in through intake funnel, glass tube, exit funnel and pollen impinges on jelly-coated slide. Instrument was calibrated by introducing known number of pollen grains (giant ragweed) into intake funnel with filtered indoor air being drawn through. Efficiency was 90% but this may vary under actual operating conditions.

Duke, W. W. - A Rapid and More Accurate Method of Determining the Pollen Content of the Air, J.A.M.A. 99:1686 1932

Durham, O. C. - A Simple Apparatus for Determining the Pollen Content of the Air, Aerologist, 11:10, 1935 Abstract - J. Allergy, 6:412; 1935

Abs. - (from Abstract in J. Allergy) Portable apparatus designed by Dr. E. V. Hill. 20-in. shaft with clip for holding glass slide. Shaft geared to handle so that it rotates as apparatus is whirled in the air. For each revolution of the shaft, the slide rotates 3x. Thus air impinging on the slide is not received at right angles but cut by slide at all angles. Equivalent of 24-hr. gravity found to be 1,930 turns. Can make test in 2 min. Gives table showing great differences in counts at nearby places within an hour or two.

Durham, O. C. - The Volumetric Incidence of Atmospheric Allergens II. Simultaneous Measurements by Volumetric and Gravity Slide Methods. Results with Ragweed Pollen and Alternaria Spores - J. Allergy - 15:226 (1944)

Abs. - This study attempts to correlate volumetric and gravity counts. Cocke attempted this in 1937 using a simple "volumetric pollen trap" with the gravity slide. The trap sampled at 2 cu. ft. / hr. He found 32% more by volume; using specific gravity of 0.5 would get 23% less by volume. Hawes (1942) used an impinger and slide. Impinger rate was 5 cu. ft./hr. on grass pollen and he obtained 19% less than calculated value using Stoke's Law. (12-59% faster fall than theoretical).

Abs. (Cont'd.) Durham used Hawes device and gravity slide method atop Abbott Laboratories (gravity slide was not protected on top). Adopted a 2nd sampler (because of wide variations in ratios) which was a nitrocellulose filter (Keitt & Jones) @ 60 cu. ft./hr. Filter was dissolved in 50 cc of liquid (3 parts by volume of ether to 1 part of absolute alcohol). Added 1 drop of saturated solution of fuchsin. Evaporated to syrup while stirring, poured samples to clean slides & evaporated to dryness, obtaining collodion films < 20μ thick. Determined proportion of sample on slides to total by weighing. Avg. runs were 7 hrs: gravity counts per cm^2 multiplied by factor to convert to 24-hr. result. Got good agreement between two volumetric methods, poor correlation with gravity slide (latter should be 1/12.7 of count volumetrically for 24-hrs). Instead it was some times as high as 1/2 or a 700% error. On a few days gravity count was low but only once did the proportion agree with:

$$\text{No./cu.yd.} = \frac{6.97 \times \text{No./cm}^2}{\text{rate of fall} \times 24 \text{ sec}}$$ (Used rate of fall of 0.022 ft./sec for specific gravity of 0.55)

$$= 13.2 \times \text{no./cm}^2 \text{ (Durham used 12.69)}$$

$$\text{Stokes' Law } V_{\text{cm/sec}} = \frac{2gr^2(d_1 - d_2)}{9k} = \frac{2 \times 980 \times r^2 \times d_1}{9 \times .00018 \times 10^8}$$

with r = 10μ and d_1 = 0.55 gm./cc, got 0.0218 ft./sec. or 0.657 cm/sec.

Slight correlation with high gravity counts and high wind but are unpredictable. Recommended Hawes device. Recommended continue relying on gravity slides, realizing inaccuracy.

Durham, O. C. - The Volumetric Incidence of Atmospheric Allergens IV. A Proposed Standard Method of Gravity Sampling, Counting, and Volumetric Interpolation of Results J. Allergy - 17:79 (Mar. 1946)

Abs. - A proposed standard device was developed and compared with various other gravity slide methods in use. It was also compared with volumetric counts/cu.yd. obtained with the Hawes impinger. The new device caught less pollen at 12 of 13 places than old devices. Ratio of volumetric to gravity averaged 3.6 (Vol. = 3.6 x Grav.) varying from 1.1 to 7.0 on 17 days at N. Chicago & Milwaukee. A standard conversion factor of 3.6 for short ragweed is suggested. Factors for 40 other species given, varying inversely with rate of fall as compared to short ragweed pollen. If diameter varies, new factor should be computed. Device is now standard pollen sampler. Recommended sampling atop tall building in business district.

Durham, O. C.; Black, J. H.; Glaser, J.; Walzer, M. - Preliminary Report of the National Pollen Survey Committee of the Amer. Acad. of Allergy on Proposed Standardization of Pollen Counting Techniques J. Allergy - 17:178-180, May, 1946

Abs.- Uniform slide shelters distributed to a group of collaborators to determine comparative counts with old shelters and the practicability of its use. Ratios old/new varied 0.92-5.43, all but 1 being >1.00. Committee agreed on a few changes and reports the suggestions for standardization using gravity slide method. Counts to be reported/1 sq. cm. (Mimeographed standard procedure and drawing of apparatus available from Committee).

Durham, O. C. - The Volumetric Incidence of Atmospheric Allergens V. Spot Testing in the Evaluation of Species. J. Allergy - 18:231 (1947)

Abs.- Two methods were used to make spot tests under optimum conditions for maximum counts. Used the Hill dust pump (impinges in 3 spots on oiled slide. 4.5 cu.in. per stroke) and air whip (36" aluminum rod swung in circle with slide facing wind on end at 100 turns per minute - usually 200 total). Table given with maximum daily counts (24 hr.) and maximum spot counts. Does not show which device was used in spot tests or give any figures on calibration with Hawes slit impinger. (States that air whip was carefully calibrated with Hill dust impinger & Hawes impinger). Record for giant ragweed pollen was obtained at Highland Park, Ill. on Aug. 21, 1945 with 9,600,000/cu. yd. (?) At that time one would be inhaling more than 6,000 gr./breath or >100,000/min. Pollen about 50' high visible 200 yds. away.

Hawes, R. C.; Small, W. S.; Miller, Hyman - An Apparatus for Determining the Pollen Content of the Air and Notes on Pollen Survey Methods J. Allergy 13: 474-487, 1942

Abs.- Need air counts sensitive in lower ranges, not in higher ones because degree of patients' sensitiveness is not precise.

Cocke's formulae: $n = \frac{2930\ fW}{D^2}$; $W = 1.53 \times 10^{-9}\ f'DN$

n = No./cu.yd.; W = wt. in gms/cu.yd.; D = diam. in μ; N = no. / sq. cm. (24 hr. slide); f and f' are shape corrections to allow for departure from sphericity, surface smoothness, and unity average density.

Impingement sampler: Air drawn through slit 0.2 mm x 10 mm into partially evacuated box, at rate of 0.1 cfm. average velocity in slit is 2,400 cm/sec. or 53 mph. Slit is in rubber-gasketed cover plate. Air strikes adhesive coated slide 2mm away. Slide moved by electric clock mechanism lengthwise @ 2.5 mm/hr. (24-hr. run occupies 3/4 of length of 3" slide). Pump (Haddaway Mfg. Co., Los Angeles) exhausts through silencer. Water manometer measures vaccum in box. 26 runs made (20-26 hrs.) Dec. 28, 1938 - Jan. 31, 1939. Got no consistent diurnal changes in pollen count. Rain quickly and completely freed air of pollen. Fairly close correlation with gravity method. Suggests reporting gravity method as % of that obtained for a previous year rather than a definite number.

MacQuiddy, E. L. - Air Studies at Higher Altitudes J. Allergy 6:123-127, 1935

Abs. - Airplane studies near Omaha, by methods of Stakman and Meier. Pollen, spores and bacteria. Exposed 2 plates, 1 slide simultaneously. One plate each for spores and bacteria, slides for pollen. Incubated plates 48 hrs. Exposures were 3 min. Bacteria decreased at 3000-4000 ft., further at 5000-6000 ft. Spores dropped off at 4000-5000 ft.; Pollen at 3000-4000 ft. Pollen was found above 5000 ft. but not identified and not believed to be local.

National Research Council, Committee on Apparatus in Aerobiology: Techniques for Appraising Air-Borne Populations of Microorganisms, Pollen, and Insects Phytopathology 31:201 1941

Scheppegrell, William - Hay Fever and Hay Fever Pollens Arch. Int. Med. 19:959-980, 1917

3. SPECIFIC GRAVITY OF RAGWEED POLLEN

Crawford, J. H. - Determination of the Specific Gravity of Ragweed Pollen (Ambrosia elatior) and Conversion of Gravity Sample Counts to Volumetric Incidence. Public Health Reports 64:38 (Sept. 23, 1949) pp 1195 - 1200.

Abs. - No appreciable difference in weight of commercially-dried and air-exposed pollen. Specific gravity determined in two ways:

(a) Elutriation (sketch of apparatus) in cylinder using V at axis = 2 x V (avg.) Rate of fall determined as 1.58 cm/sec. or 0.0525 ft./sec. Using Stokes' law [$v = \frac{(\rho_p - \rho_a)\ 2gr^2}{9\mu}$] and assuming density of air to be negligible (ρ_a); get $\rho = \frac{9\mu\ v}{2gr^2}$. With an average diameter of 20 microns and $\mu = 180 \times 10^{-6}$ poise, $\rho p = 0.83\ v = 0.83 \times 1.58 = 1.30$ (specific gravity).

(b) Permeameter method of surface measurement. Measure pressure drop through a small column packed with pollen: $Sw = \frac{6}{\rho d}$ where Sw = surface / gram; ρ = density; d = diameter (cm). Sw was 2280 cm/gm pollen. [Ed. note: This probably should be cm^2/gm].

$$\rho p = \frac{6}{Swd} = \frac{6}{2280 \times 20 \times 10^{-4}} = 1.3 \text{ (specific gravity)}.$$

It is claimed that elutriation minimizes the influence of charges on pollen grains and explains great difference from Durham's findings of specific gravity = 0.55.

For converting gravity counts to volumetric counts, author suggests using Dahl's modification of Schoppegrell formula: $n = \frac{6.97N}{Vt}$

n = no./cu.yd. air; N = No./sq.cm. slide surface; V = velocity of fall (ft/sec); t =time (hours). Using 0.0525 ft/sec. and 24 hrs. as t:

$$n = 5.53\ N$$

[Ed. Note: This is a much higher value than proposed by others due to increased V of fall determined herein.]

Durham, C. C. - The Volumetric Incidence of Atmospheric Allergens I. Specific Gravity of Pollen Grains - J. Allergy 14:455 (Sept. 1943)

Abs. - Durham suggests that volumetric pollen counts are desirable as with bacteria in either water or air. The cubic yard has already been suggested, probably because human intake of air is measured in cu. yds. Formula for converting gravity counts to volumetric by Scheppegrell, as discussed by Cocke and revised by Dahl: -

$$n = \frac{6.97 \times N}{V \times t}$$

(n = No. grains/yd^3; t = 24 hrs.
(N = No./cm^2 gravity slide.
(V = ft./sec.

Dahl expressed Stokes' law: $V = \frac{2gr^2 (d_1 - d_2)}{9K}$ g = acceleration due to gravity, 980 cm/sec^2; r = radius; d = density; K = coefficient of viscosity, which for air is .00018 @ 20-23°C

Scheppegrell omitted d_1-d_2; Cocke agreed because the specific gravity of particles was not known. Dahl questioned omitting density factor. Durham attempted to weigh and measure pollen grains to determine specific gravity. Duke & Thommen have agreed fairly closely on weight (gm/cc.) of loose, dry untreated pollen (ragweed: Diam = 15-22μ; gm/cc = 0.30-0.34). Densities above are not true due to large empty space around grains when weighing many. Also grains change materially by drying out, density changes with humidity. Experiments (1) Commercially dried pollens lost very little weight upon desiccation (up to 4%); (2) Commercially dried pollens picked up 47-100% in wt. when exposed to high humidity for several hours. Volumes computed from measurements (dry and moist) and also from volume occupied in graduated cylinder, less 26% (assumed to be spheres in both cases). Ragweed increased in volume only 8% from dry to moist. Weights were then made (per grain in gms. x 10^{-9}) dry and moist by suspending suitable amount of pollen in lactophenol solution and counting in Levy blood counting chamber. Specific gravity derived from weight and volume of 1 granule. Common ragweed was 0.55; southern ragweed = 0.50; grasses approached 1.0; tree pollens about 0.90.

Durham, O. C. - The Volumetric Incidence of Atmospheric Allergens III Rate of Fall of Pollen Grains in Still Air. J. Allergy - 17: 70-75, March 1946

Abs. - Measured average time of fall and calculated the rate of fall of various pollens in grounded iron water pipe 48" long x 51 mm diam. (inner)

placed vertically in unventilated, unheated room. Horizontal swing gate at top, 1 sq. cm. hole at bottom with glass slide. Experiments with different sized tubes gave nearly half the rate with small diameter tubes over that with large. Dyakowska and Knoll used 120 mm and 35 mm diameter tubes, Dyakowska getting much higher figures for rate of fall. Durham compared favorably with Boimer who used 35 mm tube. [Ed. Note: Durham picked iron pipe because it gave the lowest rate of fall, apparently since other tubes gave higher than theoretical rate].

4. CALCULATING POLLEN CONCENTRATION OF THE AIR

Cocke, E. C. - Calculating Pollen Concentration of the Air J. Allergy, 8:601-606 (1937)

Cocke, E. C. - A Method for Determining Pollen Concentration of the Air J. Allergy - 9:458-463 (1938)

Dahl, A. O. and Ellis, E. V. - The Pollen Concentration of the Atmosphere Pub. Health Rep. 57:369-376 Mar. 13, 1942

Abs. - Recommend reporting gravity slide counts per unit area of slide surface: Count 25 fields (100X); Count/cm^2 = $\frac{100}{25A}$ x N where N = No. grains counted in 25 fields: A = Area field in mm^2. Converting to a volumetric basis (from slide counts) was originated by Scheppegrell (1917) using Stokes' Law:

$$n = \frac{6.97 \times N}{V \times t}$$

n = no. gr./cu. yd. V = Velocity (Stokes)
N = no./cm^2 of slide. t = time (24 hrs.)

$$V = \frac{2\ gr^2(d_1 - d_2)}{9K}$$

g = 980 cm/sec^2; r = radius; d_1 and d_2 = density of sphere and air, respectively. K = coefficient of viscosity (0.00018)

Scheppegrell made errors; these were pointed out by Cocke who made other errors. Both used $d_1 - d_2 = 1.00$. $d_2 = 0.0012046$ (Specific gravity of Air). (Editor's note: Too fine mathematics was used and authors did not take account of impingement)

Duke, W. W. - A rapid and More Accurate Method of Determining the Pollen Content of the Air - J.A.M.A. 99:1586 1932

Durham, O. C. - The Volumetric Incidence of Atmospheric Allergens - II. Simultaneous Measurements by Volumetric and Gravity Slide Methods. Results with Ragweed Pollen and Alternaria Spores - J. Allergy - 15:220 (1944)

See Subject 2 for Abstract.

Durham, O. C. - The Volumetric Incidence of Atmospheric Allergens IV. A Proposed Standard Method of Gravity Sampling, Counting, and Volumetric Interpolation of

Results - J. Allergy - 17:79 (Mar. 1946)
See Subject 2 for Abstract

Durham, O. C.; Black, J. H.; Glaser, J.; Walzer, M. - Preliminary Report of the National Pollen Survey Committee of the Amer. Acad. of Allergy on Proposed Standardization of Pollen Counting Techniques - J. Allergy - 17:178-180, May, 1946

See Subject 2 for Abstract.

Hawes, R. C.; Small, W. S.; Miller, Hyman - An Apparatus for Determining the Pollen Content of the Air and Notes on Pollen Survey Methods - J. Allergy 13: 474-487, 1942

See Subject 2 for Abstract.

Scheppegrell, William - Hay Fever and Hay Fever Pollens Arch. Int. Med. 19:959-980, 1917

5. AERIAL DISTRIBUTION OF RAGWEED POLLEN

Balyeat, Roy M. - Factors Which Determine the Pollen Content of the Air J. Lab. & Clin. Med. 12:1151-56, 1927

Velz, C. J. - Factors Affecting Aerial Distribution of Ragweed Pollen (Typed Paper).

Abs. - Need to develop and test procedure to evaluate effectiveness of ragweed control with 2,4-D. Pollen counts - (1) Gravimetric - Standard American Academy of Allergy method of slide exposure for 24 hrs. - reported as grains/cm^2. These counts do not correlate with quantitative measures, because normal air movements are not quiescent or streamline flow. Durham has developed a conversion factor based on simultaneous counts (approved by National Pollen Survey, ...). Count per cm^2 x 3.6 is = count/cu.yd. air. (Preferable to applying Stokes' Law. However, data show considerable scatter and ratio from line of best fit is 2.8). Durham admits gravity counts show wide variation compared to volumetric counts. (2) Volumetric - remove pollen from measured flow of air passing through apparatus. Concentration = grains/cu.yd. Provide consistent, reliable data but are expensive and not readily adapted to routine operation without careful supervision.

Present records are based on widely separated stations, variously reported as gr./cm^2; gr./1.8 cm^2; gr./cu.yd. (converted from slide counts).

Probable factors involved:

(1) Wind direction and intensity in relation to source. Prevailing wind varies day to day and hour to hour. Also, due to unequal heating, up- or down-drafts are common.

(2) Precipitation, relative humidity and sunshine influence day to day

distribution and also pollen production.

(3) Orographic effects of local topography alter distribution of pollen. Deep valley may be free; mountains act as guide vanes or shelter walls; open level areas may serve as pathways for distribution by wind.

(4) Vegetative cover and characteristics of pollen production influence concentration and distribution of pollen.

Trends shown by weekly average of daily counts (Fig. 2). Ragweed discharges a slug of pollen between 6 and 10 AM., can be discharged by one gust of wind, so a continuous recorder of momentary concentrations is needed. 17 sampling stations were set up (Walzer) in 1947 obtaining 24 hr. slide counts. Results show effect of rain, topography, wind direction on counts.

Logarithmic decline in pollen count from source with distance:
$P_L = 2 - k^D$ P_L = log of % concentration of pollen remaining at any distance D from the source. k = logarithmic rate of decline. K varies from .01 - .02 (mean .017)

% Initial Conc.	Dist. from source (mi.)
100	0
75	7.3
50	17.5
25	35.5
10	58.3

The theory is proposed that the decrease in pollen counts with distance depends on the probabilities of dispersion with turbulent air flow (longitudinal, transverse and upward), rather than subsidence or sedimentation. The 24-hour slide count may be taken as an integration of these distributions. The above does not account for initial momentary distribution in the immediate vicinity of ragweed plant following release of its daily slug. A transition is observed from 10 million /cu. yd. at the plant to 500 - 1000/cu. yd. in the general air. No data are available in defining this concentration transition.

6. Pollen Counts

Abbott Laboratories - Pollens and Spores - Botanical Research Department, Abbott Laboratories, North Chicago, Illinois

Abs. - Gives graphs and tables as follows: (1) Pollen Seasons (graph) by state and city for (a) Trees (b) Grass (c) Ragweed.

(2) Distribution of Hay Fever Pollens of late summer and fall (Map of U.S.) (3) Pollen Content of Air - July through Oct. (Table) (4) Ragweed Pollen Season by days Aug. through Sept. (Graphs for 32 cities) (5) Specimens obtained in recent Aerobiological Studies (Photomicrographs) (6) Comparison of Alternaria and Hormodendrum Spores with Ragweed (Map & Graph).

American Academy of Allergy - Report of the Pollen Survey Committee of the American Academy of Allergy - T. M. Squier, Chairman, O. C. Durham, Technical Director - J. Allergy - 20:148-155 Mar. 1949

Abs. - This consists of a long table giving ragweed pollen counts/cu.yd. of air for 1946, 1947, 1948; maximum count for 1948; open date 1948; Ragweed index. (In this tabulation Buffalo has changed from the 100 originally set to an index of 52). Cities with index of 100 or more are: Decatur, Peoria and Rockford, Illinois; Indianapolis; Ann Arbor; Remson, N. Y. (150); Toledo; Dallas; Madison, Wis.; (Cincinnati is not in list). [Ed. note: Method of converting from gravity to volume not given].

APHA - Committee on Air Pollution APHA - Report on Public Health Significance, Distribution and Control of Air-Borne Pollens (Engineering Section) - H. A. Whittaker, Chmn.; John Buxell; G. M. Fair; S. E. Jennings: Sol Pincus AJPH Vol. 39, No. 5, May 1949, Part 2 Year Book (1948-49) pp 86-102.

Abs. - About 2-3 million are affected East of Rockies; in 1935-6 hay fever was 4th on list of chronic diseases (14.3/1000 adults 20-64 yrs. old). Dr. Ellis estimates 2-4% of population of U. S. suffer. Approximately equal in sexes. Susceptibility is an acquired state, called allergy. Symptoms - repeated sneezing and swelling, congestion and discharge from nasal mucosa. Starts abruptly and continues over long period. Similar effect on eyes. Develops in babies or not until past 60, but in most before 30. No recorded mortality from hayfever alone. Pollen asthma occurs in about 35% of hay fever subjects in New York (Thommen); 54% for Chicago (Huber); 17% with less than 5 attacks of hay fever and 2/3 with 25 or more attacks (Ellis). Pollens must have (1) buoyancy (2) abundance (3) allergenic toxicity. Entomophilous plants excluded (insect-pollinated); amphiphilous (insect and wind) doubtful; true anemophilous (wind) form important causes of hay fever - but not all-important.

The two ragweeds are short (Ambrosia elatior or A. artemisiifolia) and giant (A. trifida). Hay fever seasons - (1) Early spring from pollens of elms, oaks, birches, poplars, pecan (South), boxelder (West and Mid-west) (2) early summer from grasses (sweet vernal-, June, Orchard, Timothy, Red top, Bermuda (South and West) Johnson (South and West). (3) Autumn (80%) short and giant ragweed, false ragweed and cocklebur, and in West, sagebrushes, mugworts, wormwoods. Ragweed seeds viable after 40 yrs. in sand. Ragweed is a "Pioneer" plant, others take over. Pollen diameter - 15-45 μ. Pollen 20 yrs. + old (dry) is active to allergic individuals. Tree pollen numbers

10,000-1.8 million gr./flower; 2,000 million - 12,500 million gr./tree (Erdtman). Pollination heaviest in early morning accelerated by wind velocity. Pollen grains may go 20-30 miles to sea and a few 600 miles. They may be > 4000 ft. up. Durham claims pollen in toxic amounts may be blown hundreds of miles, but within 3-4 mi. of city is important. Reduction in numbers varies at least as square of distance from point of production and is probably reduced much faster. Meteorological conditions: (1) Precipitation - determines extent of growth and number of plants. Sustained rains are required to wash out pollen from air (slow rain 2-3 days will nearly clear air). (2) (a) Velocity of wind - number of grains on slide proportional to wind velocity (b) Direction of wind - from plant to people or reverse.

Sampling:

Pollens vary from place to place, hour to hour. Volumetric Methods: (1) Erdtman Air Filter Method - small vacuum cleaner with bag replaced by plaited filter paper supported on metal frame, with air measurer. (2) Wells Centrifuge - 2 concave discs face to face. Lower disc whirls rapidly and air drawn between discs is projected onto celluloid foil supported by a collar surrounding the slit. Can determine amount of air. (3) Continuous pollen measurement - apparatus with clock-work mechanism moving a slide across a jet of metered air which impinges on it through a slit. The fluctuations of pollen density are recorded and can be measured by microscopic counting. Various gravity measures - expose petrolatum or glycerine-jelly coated microscope slide, held horizontally with sheltering device to protect it from rain and fall of soot and dust. (See Appendix B. for proposed standard by AAA). Use magnification of 100x. Count and identify. 25 gr/cu yd is sufficient to produce hay fever symptoms (Feinberg & Steinberg). Corrected for Schoppe-Prell's error and allowance for spicules on pollen grains should produce a value of 196 gr./cu.yd. or 3,920 inhaled/day (assuming individual inhales 20 cu. yds./day). Durham says concentration less than above "can hardly be regarded as a severe hazard for the <u>average</u> ragweed sensitive person". Gottlieb and Urbach say can't determine clinically significant concentration of pollen as individuals vary greatly in sensitivity. Local surveys: (1) by published surveys on hay fever plants (botanists) (2) by a field survey - collect and identify air-borne samples. See tables of pollen counts in Appendices C&D (by Durham) (counts/1.8 cm^2 by gravity method). Dr. Bernton points out that over the minimum amount required to produce symptoms, more pollen does not increase disease proportionately.

Control:

(1) Individual's action: (a) Avoid undue exposure to pollen (b) Avoid foods which aggravate. (c) Avoid excessive physical action, fumes, dusts and chilling of body. (2) Preventive or Immunizing Treatments (a) Pre-seasonal injections of pollen extract (b) Similar, but during season (c) Injections at regular intervals throughout year. (3) Move to hayfever - free areas - not recommended (4) Remove pollen from air - as respirators (not good); filters for house air are satisfactory. (5) Prevent discharge of pollen into air - by eliminating plants (there are other reasons for weed control). Enforcement of ordinance is not effective; cutting and pulling not good. Control weed cutting

or grubbing - fairly effective, but costly. Plant denuded areas and spray with 100-1000 p.p.m. 2,4-D (stimulates growth abnormally; 10 p.p.m. gives beneficial results). The 2,4-D is non-corrosive, non-irritating to skin, non-explosive, apparently non-toxic to animals and man; selective to broad leaf plants, but there are exceptions; acts slowly - requires 1 month; most effective in moist soils and more rapid in sun; efficiency reduced if applied within 4 hrs. of rain. It still hasn't been demonstrated that any weed-killing program will lower appreciably the amount of pollen in a city. Best chance is if (1) prevailing wind is from areas free of ragweed plants (pollen) (2) area organized is very large. Question - how large area is required?

Durham, O. C. - Cooperative Studies in Ragweed Pollen Incidence - J. Allergy, 1:12-21 (1929)

Durham, Oren C. - The Pollen Content of the Air in North America - J. Allergy 6:128-148 Jan. 1935

Abs. - The first atmospheric pollen records in U. S. were made by Dr. Marsh in 1875 and 1876 at Patterson, N. J. and New York City. Then there were none until Schoppegrell made them at New Orleans in 1916. In 1928 a National survey started. Gives tables, maps and charts. Most ragweed pollen is from short (Ambrosia elatior) and giant (A. trifida).

Durham, Oren C. - Evaluation of the Ragweed Hay Fever Resort Areas of North America - J. Allergy 8:175-180, 1937

Abs. - Slide exposures made in 1934 and 1935 in nearly 100 localities. (a "hay fever day" is one during which the count was 25/1.8 cm^2 or more - considered also as 25/cu.yd. or more). Table shows (1) average number of hay fever days per season (1 point/day). (2) Maximum atmospheric contamination (1 point/100 grains) (3) Seasonal total (1 point/200 grains). (This was determined after selecting Buffalo as 100 points for an index on the arbitrary scale).
Buffalo: (1) 35 days = 35 points; (2) 2000 maximum count = 20 Points; (3) 8992 total seasonal count = 45 points; Total = 100 points.

Durham, O. C. - Holiday from Hay Fever - Chicago Motor Club, A.A.A., 66 E. S. Water St., Chicago.

Abs. - Practically all territory east of Rocky Mountains, with exception of some of Northern Great Lakes Region, New England and South Florida grows ragweed in sufficient amount to produce symptoms in susceptible persons. Upper Michigan may get some pollen with a high South or South-west wind. At least 1 person in 50 is definitely susceptible to pollen of certain weeds and grasses. Going west, sagebrush or Russian thistle pollen may cause hay fever in some. Table of index figures given [index based on (a) length of season, (b) maximum concentration of pollen in air, (c) total seasonal fall of pollen. Critical limit index = 10; prefer values below 5].

Durham, O. C. - Our National Parks as Ragweed Hay Fever Refuges - JAMA, 138: 126-127 Sept. 11, 1948.

Abs. - Tabular Data - Atmospheric Ragweed Pollen Data for National Parks and Recreational Areas. Figures for "Days of high incidence" refer to those with greater than 25 grains/cu.yd. "Maximum Atmospheric Concentration" = max. grains/ cu. yd. during any 24-hr. period. "Seasonal Total" = cumulative counts/day for entire season. "Index" = figure based on average length of season, maximum concentration and average seasonal total. Areas with index of 10 or more are not recommended; prefer less than 5; index less than one is excellent.

Durham, O. C.: Air-Borne Allergens in the National Parks - Reprint from: J. of Allergy 20:4 pp 255-263 (July, 1949)

Abs. - This is a more complete report than the preliminary one in 1948 (JAMA 138:126). Of the 29 National Parks, pollen investigations were made in all but 4. Field survey and atmospheric study (Rod device) made in most instances. Pine pollen not included, but tables (13 plus a summary table) include tree, grass and weed pollens but not spores. Concludes that Everglades & Isle Royal National Parks are only ones East of Rocky Mountains recommended as refuges from ragweed pollen. Glacier is better than the Colorado, Utah and Arizona parks because of sagebrush at the latter.

Gottlieb, Philip M.; Urbach, Erich - The Distribution and Pollination Times of the Important Hay Fever-Producing Plants in the U.S. - J. Lab. & Clin. Med. 28:1053-1070, 1943 (June)

Gottlieb, Philip M.; Urbach, Erich - Pollen Surveys in the U. S.: A Critical Review - J. Lab. & Clin. Med. 28:1426-1440, 1943

Patterson, P. M. and Gay, L. W. - The Pollen Content of the Air and Its Relation to Hay Fever in Baltimore, Md., during 1930 - J. Allergy 3:282-295 (1932)

Rosendahl, C. O.; Ellis, R. V.; Dahl, A. O. - Air-borne Pollen in the Twin Cities Area with Reference to Hay Fever - Minn. Med. 23:619-625 (1940)

Squibb, E. R. & Sons - Hay Fever: A Geographical and Botanical Survey - E. R. Squibb & Sons, New York, 1937

Stern, Arthur C. - Pollen in the Air - Heat & Vent. 42:63-66 Nov., 1945

Wodehouse, R. P. - Atmospheric Pollen - J. Allergy 4:220 1933

7. HAY FEVER

APHA - Committee on Air Pollution - Report on Public Health Significance.

Distribution and Control of Air-Borne Pollens (Engineering Section) H. A. Whittaker, Chmn.; John Buxell; G. M. Fair; B. H. Jennings; Sol Pincus

See Subject 6 for Abstract.

Durham, O. C. - Holiday from Hay Fever Chicago Motor Club, A.A.A., 66 E. S. Water St., Chicago, Ill.

See Subject 6 for Abstract.

Feinberg, S. M. & Steinberg, M. J. - Studies on Pollen Potency J. Allergy - 5:19, 1933

Feinberg, S. M. - Recent Developments in Asthma and Hay Fever - J. Allergy - 8:282-309 (1938)

King, J. H. - Hay Fever due to Alternaria Spores in the Cincinnati Area J. Med. 20:34 (1939)

Patterson, P.M. and Gay, L. M. - The Pollen Content of the Air and Its Relation to Hay Fever in Baltimore, Md., During 1930 J. Allergy, 3:282-295 (1932)

Pratt, H. M. - Species Specificity of Alternaria in Asthma and Hay Fever J. Allergy 12:431 1941

Rosendahl, C. O.; Ellis, R. V.; Dahl, A. O. - Airborne Pollen in the Twin Cities Area with Reference to Hay Fever Minn. Med. 23:619-635 (1940)

Scheppegrell, William - Hay Fever and Hay Fever Pollens - Arch. Int. Med. 19:959-980, 1917

Squibb, E. R. & Sons - Hay Fever: A Geographical and Botanical Survey E. R. Squibb & Sons, New York, 1937

USPHS - Hayfever - Washington: Govt. Ptg. Off. June, 1946 Health Education Series No. 17

Abs. - This leaflet tells of the several types of seasonal hayfever: (1) Spring - caused by tree pollens (in East late Mar. through May) (2) Summer grass pollens (timothy, red top) (End May to mid-July) (3) Fall - usually due to ragweed (most widespread) (Mid-August to first frost). Diagnosis - Allergy tests. Treatment - (1) Immunization injections each year, a few days apart before season. Need complete series. (2) Removing pollen from air - filtering, etc. (3) Change location - see "Y. Hay Fever" - Durham. (4) Medicines - Drops and sprays, pills. [Ed. note: Doesn't mention 34-d].

Wodehouse, R. P. - Weeds, Waste and Hayfever - Natural History 43:150 - 163, 178 Mar., 1939

Wodehouse, R. P. - Book: Hayfever Plants - Chronica Botanica Co., Waltham, Massachusetts, 1945

8. ALLERGENS

Durham, O. C. - Incidence of Air-borne Fungus Spores, I. Alternaria - J. of Allergy - 8:480 July, 1937

Abs. - The subject of fungus spores regarding asthma and hayfever is quite controversial. Routine counts are made on gravity slides at 100X and reported per 1.8 sq. cm. The spread of season is greater than in ragweed but peaks are at about same time. Alternaria predominates over ragweed in central and southern U.S. and in the west; ragweed predominates on east coast but it is also lower there (both belts center over agricultural states). Tables, graphs and map are presented.

Durham, O. C. - Incidence of Air-Borne Fungus Spores II. Hormodendrum, Alternaria, and Rust Spores - J. of Allergy - 10:40-47 Nov. 1938

Abs. - Methods of exposure and counting are the same as Durham used for pollen since 1928. Numbers are reported/1.8 sq. cm. from 24-hr. gravity slides. Alternaria spores are lighter than ragweed pollens but usually are single. Hormodendrum vary greatly in size and float in masses (2-100). Both are found in all parts of U.S. (maps, graphs, and tables are shown). Seasons are about the same. "Index" (same as for ragweed pollen index); Computed: 1 point for each day that the count equals or exceeds 25; 1 point for each 100 spore particles in maximum count; 1 point for each 200 spore particles in average seasonal count.

Durham, O. C. - Air-borne Fungus Spores as Allergens Reprint from Aerobiology, Publication No. 17, Amer. assoc. for Advancement of Science pp 32-47 (1942)

Abs. - This chapter is essentially a combination of Durham's 2 papers on Incidence of Air-borne Fungus Spores. It also includes, however, much data on ragweed under headings: historical, methods of sampling and counting, identification and classification (not much in latter on ragweed), technic of slide counting.
Shows same graphs and map as II. paper noted above. Counts are on basis of Number/1.8cm^2 on slide exposed for 24 hours (not standard). Suggests use of impinging air on slide (either moving slide or air) as sampling method.

Durham, O. C. - Air-Borne Allergens in the National Parks - Reprint from: J. of Allergy 20:4 pp 255 - 268 (July, 1949)

See Subject 6 for Abstract.

Rackemann, F. M.; Randolph, T. G. and Guba, E. F. - The Specificity of Fungous Allergy J. Allergy 9:447 1938

Waldbott, G. L.; Ascher, M. S.; Ackley, A. B. - Fungi, Relation to Respiratory Allergy - Jour. Mich. State Med. Soc. 39:645 1940

Waldbott, G. L.; Ascher, M. S. - Rust and Smut, Major Causes of Respiratory Allergy - Ann. Int. Med. 14:215 1940

Wittich, F. W. - Further Observations on Allergy to Smuts Lancet 49:382 1939

9. RAGWEED CONTROL

Fletcher, Alfred H. - The Practical Administration of a Ragweed Control Program - Typed copy of talk before Conference on Ragweed Control, Univ. of Cincinnati, May 25, 1949

Abs. - (1) Epidemiology (generally believed that hay fever is largely caused by ragweed pollen).
(2) Botanical survey (locate and map ragweed areas).
(3) Engineering Control Program (a) survey and cost estimate; (b) spraying operations; (c) reporting and supervising the operations).
(4) Engineering Control Evaluation (reduction in weeds and pollen; analysis of results).
(5) Plant ecology (as influenced by control operations).
(6) Research - Chemicals of 2,4-Dichlorophenoxyacetic acid:
(a) Sodium salt - Acid Equivalent - 85%. Used with wetting agent (powder form) in solution. (This is used by N.Y.C.)
(b) Butyl Ester - 39.8% acid equivalent. Emulsifiable oil base. Particularly good for grain and woody types.
(c) Amine salts - 40% acid equivalent. In water solutions, ethanol amine form.

Best results are obtained by spraying when weeds are actively growing, generally near bud stage. Butyl ester is volatile, fumes may drift. Drench 90% of foliage. Keep off hedges, flowers, vegetables, trees, especially tomatoes and roses. Nozzles - 0.079" diameter general purpose adjustable orchard guncone-shaped spray; 0.079" orifice with 3-headed adjustable slot-shaped opening for fan-shaped spray; 48-$\frac{1}{4}$" fan-shaped asphalt sprayer. Pollen counts as recommended by allergists are not adequate to evaluation control work. Need concentration of pollen vertically as well as horizontally and also during various time intervals through the day. Also important are wind currents. Counts near growth often run to millions per cu. yd.; at higher elevations run from a few to 100-200/cu. yd. Need a more accurate quantitative pollen measuring device. Spraying with 2,4-D kills weeds and also encourages grasses and other plants. Overall cost is very low.

Smith, Frederick, G.; Hamner, Charles L.; Carlson, Robert F. - Control of Ragweed Pollen Production with 2,4-Dichlorophenoxyacetic Acid Science 103:473-474 Apr. 19, 1946

Vintinner, F. J. - Communities Control Ragweed and Poison Ivy New Hampshire Health News, 27:9, Sept., 1949 pp 82-84.

Abs. - Communities of Bethlehem, Jefferson, Lancaster, Laconia and Littleton inaugurated ragweed and poison ivy control, largely with 2,4-D spray. State Highway Dept. helped in each case by spraying the right-of-ways of primary and secondary highways. Was done largely by City departments such as Street or Fire Departments. Hotels cooperated and in some cases did spraying. In all cities the classification changed to "light" or "negative" for ragweed growth. Knapsack sprayers were commonly used. Some cities were formerly classified as "heavy".

Weinstein, Israel; Fletcher, Alfred H. - Essentials for the Control of Ragweed AJPH - 38:664-669 May, 1948

Abs. - Three million in U. S. suffer from hay fever (2-3%). Estimates of 35 - 54% also have pollen asthma. In sampling for pollen concentration need a number of stations. Need accurate related meteorological and ecological data (there was considerable variation in counts of five New York Boroughs). Follow Amer. Acad. of Allergy standards on counting. Ragweed is a pioneer, non-competitive plant. Little is known of its ecology. Chemical 2,4-D is a selective herbicide killing ragweed in 0.1% (by weight) concentration when 90% of the foliage is wetted (approx. 200 gal./acre; 1 crew of 3 sprayed 2½ acres/day; cost of chemical is $2/acre). Apply before pollination. 2,4-D encourages intermediate plants. Need city-wide control with public funds and education.

10. SAMPLING OF AIR-BORNE BACTERIA

APHA - Committee on Air Pollution - A Bacteriological Method of Sanitary Air Analysis (Wells, Phelps, Winslow) Year Book 1936-37 Supp. to AJPH - 27:97-101 (1937)

Abs. - Method is based on centrifugal precipitation of bacteria upon a nutrient medium. Wells centrifuge: (1) pumps (2) measures air (3) collects (4) plants bacteria. (Picture & drawing) Glass cylinder must be balanced and spin at 3500 rpm. Adjusted to sample 1 cfm but can change by inserting different orifices. Media: (1) Ordinary - plain nutrient agar stiffened by 7 additional gms of agar per liter. (Incubate 4 days at 20°C) (2) Fungi - Sabourand's media (stiffened) (3) B. coli inoculated air - Stiffened EMB Agar (4) Nasopharyngeal organisms - blood hormone agar (7 drops rabbit blood to 25 ml. stiffened hormone agar) (5) Liquids. (6) Strips of celluloid foil can be placed in the sleeve to collect particles for microscopic examination.

Counting - Divide tube lengthwise into 4 parts. Slide cylinder over tubular lamp. Count 4 fields in each quarter (16 total) Special organisms - Can fish and plant to petri dishes for isolation. Gives advantages of the method. (Disadvantage - Does not break up clumps).

APHA - Committee on Bacteriological Procedures in Air Analysis - IV Report - Analytic Bacteriological Procedures - APHA Yearbook 1937-1938 - Supp. to V. 28; No. 2 Feb. 1938 pp 90-91 (W. F. Wells; E. B. Phelps; C-E.A. Winslow)

Abs. - Suggest (1) bacterial indicator of nasopharyngeal contamination in semi-enclosed atmospheres; (2) estimate adequacy of ventilation by removal of microorganisms.

Reports on works of: Gordon - 1902: Winslow & Browne - 1914; Wells & Wells - 1936; Pincus & Sterne - 1937; Buchbinder - 1938; Wells - 1938.

Recommendation - That wells paper on sanitary ventilation (AJPH Mar. 1938) be accepted. Hope to develop standard method.

APHA - Committee on Std. Meth. for Exam. of Air. Sub-Committee on Bacteriological Procedures in Air Analysis State of Suspension Report (of Sub-committee) APHA Yearbook 1939-40 Supp. to Amer. J. Pub. Health, 30:99-104 Supp. to Amer. J. Pub. Health, 30:99-104 (1940) (Wells, Phelps, Robertson, Winslow)

Abs. - Distinguish between (1) microorganisms from body tissue introduced by violent respiratory processes and (2) miscellaneous ubiquitous organisms from decomposing organic matter raised as dust. Droplet nuclei are small; dust may be large or small. Size varies with cube and mass with square of diameter. Stokes' Law - Applies to particles so small that surface resistance is large compared to gravity pull.

$$V = 2/9\ r^2\ \frac{(s-1)\ g}{u}$$

V = vel. of settling; r = radius

s = density of particle; 1 = density of fluid (air); g = gravity constant; u = viscosity of fluid (air). Any consistent system of units may be used.

Particle-size index: Count on Petri dish exposed for 15 min. compared to cylinder count indicates equivalent size of particles.
A (petri dish) = 1/15 sq. ft.; therefore the number settling in 15 min. approximates the number settling/sq. ft./min.
Centrifuge count = cylinder count.

$$\text{Ratio} = \frac{\text{Volume count (10 cu. ft. centrifuge sample)}}{\text{Area count (15 min. exposure of Petri dish)}}$$

(Table of Comparative Coarseness of Bacteria-Bearing Dusts -- gives ratio; mean settling velocity; equivalent diameter of particle)

Addenda (Phelps) - Sprayed suspensions of bacteria from broth are recovered only 1/3 by centrifuge as compared to settling in prepared plates. Recovery on plates simulates logarithmic death rate curve. Recovery by Wells centrifuge also indicates a logarithmic decrease but counts are roughly 1/3 to 1/2 of that settling in 7.5 hours. Total numbers by either are only small amount of those introduced.

Discussion (Wells) - Settling rate of droplet nuclei are (minimum value) 16 in./hr. Critical falling velocity for recovery in centrifuge is 36"/hr. Culture evaporated in chamber results in mass of nucleus of 2×10^{-10} gm. or approximately 5μ diameter. Poisson's expansion law gives relationship of number of organisms to number of colonies.

APHA - Committee - Subcommittee on Bact. Procedures in Air Analysis - Quantitating Gordon's Bacterial Test for Estimating Pollution of Air
APHA Yearbook 1940-1941 Supp. to AJPH 31:129-134, Mar. 1941

Abs. - To check for nasopharyngeal or salivary streptococcus in lactose broth, author tested with bromthymol blue to indicate acid production. (Results: one per 7.3 cu. ft. for country air to one per 0.29 cu. ft. in slum home air and one per 0.15 cu. ft. in grade school air). Tested lactose tryptose broth containing other selective substances to improve specificity:- 15 ml. broth are placed in centrifuge tube (to give 12 ml. after sampling). Divide into six parts adding 10 ml. lactose broth to one and dividing it again into six parts (further dilutions may be made). Sample six min. indoors, 30 min. outdoors.

APHA Committee - Subcommittee on Bacteriological Procedures in Air Analysis. Report APHA Year Book 1941-42. Supp. to AJPH 32: 137-141 Mar. 1942

Abs. - Lactose-tryptose broth with bromthymol blue (to indicate acid production) used for presumptive test for streptococci expelled from respiratory tract. Confirmatory medium: Gentian violet (.0002%) blood agar. Centrifuge only collects 1/3 of nuclei which settle at around 0.03 ft./min. (Ratio of plate count to centrifuge count is 0.1). Practically total recovery was attained of particles settling in excess of 0.5 ft./min.

Bourdillon, R.B.; Lidwell, O.M.; Thomas, J.C. - A Slit Sampler for Collecting and Counting Air-Borne Bacteria J. Hyg. 41:197-224 Sept. 1941

Buchbinder, Leon; Solowey, M.; Soloforovsky, M. - Alpha-Hemolytic Streptococci of Air AJPH 28 pp. 61-71, Jan. 1938.

Abs. - Used Wells centrifuge and sheep's blood agar. Samples were obtained from schools, subway cars, theaters, parks, and streets. Highest in schools - 0.15/cu. ft.; subways - 0.10/cu.ft.; streets - 0.10; theaters - 0.08; theaters (air cond.) - 0.05; park - 0.03. Schools varied from 0.09 to 0.26. About half (58.4%) of streptococci were str. salivarius; 16% str. mitis; 7-33% (8.6%) str. ignarus. Isolated various strains and ran tests on them. Concluded that presence of alphahemolytic streptococci in air indicates human pollution (from nose and throat). Also numbers indicate degree of pollution (recent occupation). Differences in strains may be due to effects of aerial environment.

Crosbie, W.S.; Wright, H.D. - Diphtheria Bacilli in Floor Dust Lancet 1:656-659 May 24, 1941.

duBuy, H.G.; Crisp, L.R. - A Sieve Device for Sampling Air-Borne Micro-Organisms Pub. Hlth. Rep. 59: 829-832 June 30, (1944) Reprint from PHR No. 2464.

Abs. - Box with air outlet (4 mm.) holds a standard petri dish with nutrient agar. Cover consists of a brass plate with 300 openings each 0.796 mm. in diameter (No. 68 drill). Cover fits airtight, fastened by 2 toggle clamps. Photograph and detail drawing. Pictures of colonies on dish. Sterilization - Wipe sieve with ethanol and flame.

	No. Runs	Bact./10 cu.ft.	150 Openings cfm.	Bact./10 c.f.
Open plate	18	7.7 ± 2.5 (10 min.)	.25	27 ± 6.4
Funnel device	18	40.6 ± 5.4	.5	31 ± 5.2
Sieve, 150 holes	18	50.2 ± 6.4	1.0	30 ± 3.7
Sieve, 300 holes	18	77.7 ± 7.9	1.5	20 ± 4.4
			1.9	16 ± 0.7

40 l./min. is about maximum rate.

duBuy, H. G.; Hollaender, Alexander; Lackey, Mary D. - A Comparative Study of Sampling Devices for Air-Borne Micro-Organisms Supp. 184 to PHR (1945)

Abs. - E. coli used in 518 cu. ft. chamber. Recommendation: Use 3 types devices simultaneously:
(1) Settling particles - by open plate method.
(2) Total organisms - by atomizing methods -
(a) Bead bubbler (Wheeler), atomizer bubbler (Moulton), Rettger aeroscope (Folin bubbler)
(3) Number of particles which contain organisms - by impinger devices - (a) Air centrifuge (Wells) (b) funnel device (Hollaender) (c) Slit device (Bourdillon) (d) bottle device (Sharf) (e) Seive device (duBuy)
Efficiencies: Atomizers - Best-Moulton (also difficult to clean, etc.); Next Rettger (small volume)
Impingers - Best - Slit (2 motors) and Seive Devices: Funnel; Wells Centrifuge (latter gets larger particles, not below .7μ)

duBuy, H.; Arnold, F. A.; Olson, B. J. - Studies on the Air Transmission of Microorganisms from the Respiratory Tract I. Lactobacillus Acidophilus as a Test Organism. PHR 62:1391-1413 Sept. 26, 1947 (Reprint No. 2809)

Abs. - Studies with H. tuberculosis have been negative. L. acidophilus was chosen for the non-pathogenic test organism and experiments were run to determine (1) if L. acidophilus is expelled by coughing, etc.; (2) if spread directly (droplets) or indirectly (suspended by evaporation of droplets); (3) concentration required in saliva; (4) if parallel results can be obtained by artificial atomization. Used 1% Dextrose broth (pH 5) and tomato juice agar (pH 5). Samplers: (1) Open Petri dish with tomato agar (2) modified Folin bubbler 1 cfm. (with test tube trap) with 10 ml. of either saline or pH 5 meat infusion dextrose broth. Incubate at 37° for 96 hrs. (3) Greeser atomizer (modified by Buchbinder) used. Only 1 bubbler sample of 17 showed L.acidophilus and the average plate count was only 4.3 in experiments with humans talking, sneezing, coughing, etc. Next tried atomizer in 500 cu. ft. chamber: got great variability, even with bubbler hooked direct to atomizer. Considerable number of bacteria do not leave the atomizer. This was checked with starch particles (too large) and with $BaCl_2$. With 80% of suspension of 53 million organisms atomized, 23.7 million organisms still remained (45%) and 8 million (15%) were washed from walls of atomizer. (does not take account of clump breakup). On basis of Petri dishes, conclude that the airborne droplets settle rapidly (4-6') [Ed. note: but don't believe that this is substantiated by data]. Conclude also that need 105-107 organisms per ml. before can recover any appreciable numbers after atomizing. [Ed. note: Atomizer may have been inefficient].

Hollaender, A.; DallaValle, J.M. - A Simple Device for Sampling Air-Borne Bacteria P.H.R. - 54:574-577 (Apr.7,1939) Reprint from PHR - No. 2055

Abs. - Funnel device, draws measured flow of air impinging bacteria on a Petri dish containing media. Apparatus - (Sectional drawing given) 3"-60° funnel set about 1 cm. above bottom of dish. Brass container with threaded bottom - top screwed tight against gasket. Sterilize by swabbing funnel with alcohol. Impinger pump was used for suction. Some crowding resulted in center when bacterial count was high (best < 200 per plate). Ran duplicate tests and tests at different rates, in chamber 10'x10'x7' (sheet metal, soldered). Used B.subtilis, sprayed with paint sprayer. Allowed 30 min. settling first. Used 12" wall fan (oscilating). Incubated for 48 hrs. at 32°C. Best rate = 1 cfm.; in series got 80% in 1st, 5% in 2nd collector.

Luckiesh, M.; Holladay, L.L.; Taylor, A.H.: Sampling Air for Bacterial Content General Electric Review, 49:3, pp 8-17, March, 1946

Abs. - Adequate air sampler needed to check efficiency of germicidal lamps. Wanted efficient, portable air-sampler. Would be important also in fundamental research on bacteria in air. Need to eliminate clumping and also to collect bacteria right on the proper media (in Petri dishes). Open plate method is too crude; Wells centrifuge only catches 10% of air-borne bacteria; bubblers lose a lot of water and require corrections; the atomizer-bubbler lacks simplicity and also has other defects; Hollaender & Dalla Valle "funnel aeroscope" is very inefficient compared to bubblers. A device consisting of a modified funnel (squat-shaped) air-sampler with provision for applying a d-c electrostatic field was developed. The funnel was of brass and formed the upper electrode, while the petri dish rested on a circular flat lower electrode. Potentials as high as 10,000 volts greatly increased the bacterial catch. An infection chamber 36" x 26" x 54" high was constructed and E. coli introduced by means of a Walton atomizer. Small low-speed fan circulated contents of chamber. Germicidal lamps installed to disinfect the air before use. Test runs with a small air tunnel at voltages of 0, 500, 1000 & 2000 V showed most colonies at 2000 V. Positive plate also caught more than negative plate with atomized air but the reverse with normal room air. Principles found led to development of an Electrostatic Bacterial Air-Sampler operating with one 10 cm Petri dish and voltage of 0-8000. Next development was a Simplex Electrostatic Air-sampler which was portable and had upper portions of transparent lucite. Operating at 0, +2000 and +4000 V, best catch was at +4000. Checking on contamination in succeeding runs showed none coming from upper electrode (less than 1/1000 of preceding sample).

Next development was Duplex Electrostatic Air-sampler with one Petri dish resting on + electrode and one on - electrode with d-c potentials of 0 to 7000V. One blower serves both sides which each receive 0.5 cfm. Dish at -7000V catches 30% more ordinary air-borne bacteria (on Tryptose Blood Agar) than on + 7000V electrode.

With artificially infected air (E.coli) the-dish caught 1/10 as much as +dish. Next a radial jet sampler was devised, the Petri dish being rotated under the radial slit at a uniform rate. Velocity of impingement at 0.5 cfm rate was about 3500 fpm, requiring a vacuum pump instead of the small centrifugal blower previously used. Operating simplex and duplex samplers in series with radial jet, results showed few organisms passing when electrostatic field used. Testing in series with one at ±7000V and next at ±14000 V, got very few organisms on the latter. Duplex sampler gave 4 to 5 times the catch with electrostatic field than without. Samplers do not necessarily overcome clumping. Duplex sampler was tested in several theaters and a cafeteria; 10-min. sampling time gave higher results than open dishes exposed for 30 min.

Luckiesh, M.; Taylor, A.H.; Knowles, T.; Sampling Devices for Determining the Bacterial Content of Air Review of Scientific Instruments 20:1, pp 73-77, Jan. 1949

Abs.- Authors developed 2 types of samplers: duplex electrostatic sampler weighing 12 lbs. using a 7000 volt electrostatic field; the second is a radial-jet (duplex) using a high velocity to impinge organisms on culture medium. Radial jet sampler does not operate in electrostatic field. Both collect organisms directly on media contained in Petri dishes. Testing the two in series indicates both to be highly efficient and reliable. Radial jet type has best use in studying efficiency of ultraviolet light.

Luckiesh, M.; Taylor, A.H.; Holladay, L.L.: - Sampling Devices for Air-Borne Bacteria Jour. of Bacteriology 52:1, pp 55-65, July 1946.

Abs.- Chemical and physical methods of appraising efficacy of systems of air disinfection have limitations. Air samplers fall in physical class and are of 2 types - those that do and do not break up bacterial clumps. Those which break clumps collect in water and require plating. Authors developed a radial jet sampler operating at 1 cfm with velocity tarough slit of 100 fps. Efficiency - 95%. Experiments indicated electrostatic charge provided greater catch and single and duplex electrostatic samplers were developed. (Rest of article similar to one in G.E.Review).

MacDonald, K. - The Efficiency of the Wells Air Centrifuge as Determined by an Air-Washing Technique Am. J. Hyg. 31 (Sec.B) : 85-97 (1940)

McConnell, W.J.; Thomas, B.G.H. - Relative Values of Methods of Enumerating Bacteria in Air P.H.R. - 40 2167-2178 (Oct. 9, 1925) Reprint #1045.

Abs. - Comperative tests made under hood with B. coli and Staph. albus (grown on beef-extract broth or agar at 37°C for 3 days). Samplers were: water aeroscope (new instrument completely described); dust determinator (filter paper); aeroscope (sand filter); Greenburg-Smith impinger. First filter paper caught bacteria satisfactorily. Filter paper and water methods were ten times as efficient as standard sand method. Impinger method did not recover organisms. Aeroscope caught all but 0.85%. Impinger probably killed bacteria by high pressure. Conclusions: aeroscope - good; dust determinator is all right but subject to contamination.

Moulton, S.; Puck, T. T.; Lemon, H. M. - An Apparatus for Determination of the Bacterial Content of Air - Science, 97:51-52 (1943)

Phelps, E. B.; Buchbinder, L. - Studies on Micro-Organisms in Simulated Room Environments. I. A Study of the Performance of the Wells Air Centrifuge and of the Settling Rates of Bacteria Through the Air. J. Bact., 42: 321-344 (1941).

Abs. - Centrifuge with nutrient agar whirled at 4-5000 rpm. Fan brings in somewhat less than 2 cfm. to bottom and air leaves vertically and tangentially to top. Wells centrifuge should catch nearly 100% of particles 2.3μ and up; 50% of 0.77μ . Experiments on survival and rate of settling in 8-ft. cubic room. Introduced bacteria by spray device (picture) at 20 psi giving greater than 10μ size particles. Used alpha-hemolytic streptococci. Sampled with Petri dishes and centrifuge. Did not get expected results. Experiments with uranine and colorimetric determinations. Only 7.9% settled (7.3% in 48 hrs.). Centrifuge recovered 62% of material settling in eight hours; can't exceed 69% of bacterial recovery and was actually obtaining 24-41%.

Pincus, Sol; Stern, A. C. - A Study of Air Pollution in New York City AJPH 27 p 321-333 Apr. 1937

Abs. - WPA Air Pollution Survey organized in September 1935. Studied fuel movement into N.Y.; House-to-house survey in Manhattan (95% of 72,784 premises). Smoke production maps based on Ringleman Chart. Used 20 observers on tall buildings. Collected soot in copper cans 5" diameter x 8" deep, except for 1 month, on top of 1 - and 2 - story buildings. Reported in tons/mi.^{2} (used 130 cans). Analyzed into soluble and insoluble matter, latter was analyzed further into solids, ash, combustible matter and tar (CS_2 Soluble). Soluble matter was analyzed as to solids, SO_3, NH_3, Cl (as NaCl) and ash. Also took impinger samples for dust count, SO_2 and NH_3 . Used CO determinator.

Pollen Work - Used slides coated with glycerine jelly dyed with basic fuchsin. Exposed daily for 24 hours each at 9 locations in the five boroughs. Count for each of common tree, grass and weed pollens, noting particularly ragweeds. Figure shows results of differential counts - not on volumetric basis.

Bacteriological work - Used Wells air centrifuge in schools, subways, theaters (also streets and parks). Got 18 hr., 37°C counts on (1) sheep's blood beef infusion agar and (2) beef infusion agar. Blood agar numbers exceeded plain agar numbers. Got higher counts in schools and subways. Also checked for all streptococci, Beta hemolytic and Alpha hemolytic (latter were 18 to 450 times as prevalent).

Proctor, B.E.; Parker, B.W.: Microorganisms in the Upper Air Chapter in: Aerobiology Pub. No. 17, AAAS 1942 (pp. 48-54)

Abs. Review of microorganisms in upper air, particularly bacteria and molds. Pasteur sampled at 2,000 m. elevation in Alps, Stakman (1923) first to use plane, found cereal rusts and many fungus spores up to 16,000 ft. Proctor (1934) developed a new unit, capable of sterilization, and found bacteria and molds above 19,600 ft. and yeast and pollens above 16,000 ft. Instrument developed at M.I.T. takes automatic samples and records certain meteorological data (Temp., time, altitude and volume). Relative humidity should also be recorded.

Rose, K.D.; Georgi, C.E. - A Selective Culture Medium for the Isolation of Streptococcus salivarius Proc. Soc. Exp. Biol. & Med. 47:344-347 June, 1941

Rose, K.D.; Georgi, C.E. - Comparative Study of Media Used for the Isolation of Oral Streptococci Abstract: J. Bact. 44:388 Sept. 1942.
From: Dept. of Bact., U. of Neb., Lincoln, Neb.

Abs. Tested series of media with micro-organisms likely to be found on eating utensils or in dishwater. Medium containing potassium tellurite and crystal violet inhibits organisms other than streptococci but also inhibits "typical" Strep. salivarius.
A medium containing sodium azide and potassium inhibits all contaminants but Staph. aureus and a Proteus sp.. Strep. salivarius grows without inhibition if inoculum is high enough. Since organisms are not normally present in this amount, suggest primary selective enrichment culture be used.

Schneiter, Roy; Dunn, John E.; Caminita, Barbara H - Studies in Connection with the Selection of a Satisfactory Culture Medium for Bacterial Air Sampling Repr. No. 2637 from PHR PHR - 60:799-806 July 13, 1945

Abs. Most workers have not given exact composition of the media used. Media should have (1) selectivity for fastidious micro-organisms of respiratory tract (2) inhibit nonsignificant saprophytes (3) standard composition.

Bacterial pollution may be evaluated by: (1) total bacteria present or (2) presence of 1 type considered as an index of pollution (as coliforms in water). Can use: (1) solid media - direct (2) collect in atomizer then determine MPN of liquid. Studied only the solid media - many kinds.

Most streptococci grew best on proteose extract agar, beef heart hormone agar, tryptose dextrose agar, and tryptose agar. Addition of 0.5 ml. of defibrinated sheep blood/10 ml. medium improved growth of streptococci, 0.002 gm crystal violet/l. didn't. Re concentration of agar - 1.8% is adequately stable and a higher concentration was not justified for spreader control. With Str. salivarius best results obtained on proteose extract agar. The organisms rapidly disappeared from air, dropping 90%+ in 35 min. and nearly to 0 in 15 to 2.0 hrs. (Not known whether due to dying or settling out). Proteose extract agar is recommended for trials.

Composition of recommended agar:

Proteose peptone, No. 3 Difco	20.0 gm.
Bacto-beef extract	3.0 gm.
Bacto-yeast extract	3.0 gm.
Bacto-malt extract	3.0 gm.
Bacto-dextrose	5.0 gm.
Sodium chloride	8.5 gm.
Bacto-agar	18.0 gm.
Distilled water	1 liter
Final pH	6.8±

Wells, W. F. - Apparatus for the Study of the Bacterial Behavior of Air AJPH 23 pp 58-59. Jan. 1933

Wells, W. F.; Phelps, E. B.; Winslow, C.-E.A. - A Bacteriological Method of Sanitary Air Analysis Year Book 1936-37. Supp. to AJPH 27:97-101 (1937) (See APHA for Abstract)

Wells, W. F. - Bacteriologic Procedures in Sanitary Air Analysis: With Special Reference to Air Disinfection J. Bact. 46:549-557 Dec. 1943

Abs. - Three types of procedures: (1) Sanitary survey of inhabited atmospheres (2) Experimental studies of bacterial suspensions in controlled atmospheres (3) Measurement of sanitary ventilation. Settling rate (no./sq.ft./min.):

$D.V_G = A$ (D = number/cu.ft.) (V_G = feet per minute)

Volume settling: $\log_e D/D_o = -V_G t/H$

$A_t H = D_o - D = D_o - D_o e^{-V_G t/H}$ or $A_t H = D_o$

(t = time: H = Height)
(D_o = original density)

The factor $D_o e^{-Vgt/H}$ is a small correction where time and Vg are large and H is small. Air centrifuge: $D = B/(1-e^{-12\ Vg})$
B = Centrifuge Count/cu.ft. (For particles $Vg < 0.5$, e^{-12Vg} is negligible and D = B). Total count means little; also total bacteria differ from number of bacteria-laden particles. Determine streptococcei differently from staphilococci. Sanitary ventilation expressed in "lethes".

Wells, W.F.; Winslow, C.E.A.; Robertson, Elizabeth C. - Bacteriologic Procedures in the Evaluation of Methods for Control of Air-Borne Infection - AJPH 36: 324-331 April 1946

Abs. - Microorganisms may exist in: dust (10-100μ); droplets (greater than 100μ); or droplet nuclei (2-10μ). Settling velocities are: Dust - 1 fps to 1 fpm; Droplets - greater than 1 fps; Droplet nuclei - less than 1 fpm. Droplet nuclei evaporate instantaneously and organisms settle very slowly. Phelps and Buchbinder got 0.03 ft./min. Subcommittee recommends Wells centrifuge as sampler for practical sanitary air analysis. Summary of Standard Bacteriological Procedures: I. Density of dust particles - A. Area count/sq. ft./min. (15 min. Petri dish count); B. Volume count (a) Slit sampler (b) air centrifuge, solid media II. Settling $Vg = A/B$

$\frac{(\text{Rate of Deposit})}{(\text{Density})}$ III Total bacteria/cu.ft. (filtration, washing, centrifuging - liquids); IV Average bacteria/particle = C/B or D/BV. Pathogens; Count on blood agar.

Wheeler, S.M.; Foley, G.E.; Jones, T.D. - A Bubbler Pump Method for Quantitative Estimations of Bacteria in the Air Science, 94: 445-446 (Nov.7, 1941)

II. AIR SAMPLING DEVICES - GENERAL

APHA - Final Report of the Committee on Standard Methods for the Examination of Air AJPH 7:1 (1917) 19 pp.

Abs. - Temperature - Thermometers with backing involve serious lag. Continuous recording instruments recommended, or use of chemical thermometers without backing. Thermometer should be standardized. Humidity - Sling psychrometer recommended with recording stationary wet and dry bulb thermometer. Need fan to blow air. Heat loss from warm moist surface - Kata thermometer (wet and dry bulbs heated to about 110° F noting time to fall from 100° to 90° with stop watch (Suggested limits - 45-60 seconds for wet bulb; 150-180 seconds for dry)
Air flow - Pitot tube (ducts); vane wheel anemometer (grills); cloud of ammonium chloride (low velocities); balloons; pinwheel.
Dust - Recommend Palmer (water spray) apparatus. Also sugar filter for dusty air.
Bacteria - "Number of bacteria in air does not appear to be a factor of any great sanitary significance". Recommend sand filter method (Petri) 15 mm diameter x 70 mm tube with cotton plug supporting 10 mm layer of sand (100-200 mesh). For lactose-fermenting streptococcus recommend using litmus lactose agar.

CO_2 - Petterson-Palmquist apparatus (measures air, removes CO_2 by caustic potash solution, measures air again); Haldane apparatus. Poisonous Gases - Absorption bulb (Seidell); CO by iodine pentoxide method (Seidell); Methyl Alcohol - fuchsin bisulphite method (Evolve); SO_2 - Direct titration with N/1000 iodine (Seidell & Meserve).; Benzol (3 methods given).; Metals - Absorption bulbs with HNO_3.

APHA Committee on Standard Methods for the Examination of Air - Report - Dust Procedures in Air Analysis - The Sampling and Analysis of Industrial Dusts AJPH 1935-1936 Year Book Supp. to Vol. 26; No. 3 March 1936,pp 86-97
J. J. Bloomfield

Abs. Reports on sampling apparatus and brings out superiority of impinger (P.H. Bull. No. 144). Greenburg-Smith impinger is standard device for dust sampling by PHS. Dusts are mainly 0.5 - 5μ. Concentration is greatly variable. Describes impinger and modifications. Electrostatic precipitator best used for smoke and fume sampling. Paper thimble for radioactive and explosive dusts. Owens jet for outdoor dusts and smoke. Konimeter efficient up to 15-18 million particles. Section on analysis of industrial dusts. Description of counting impinger samples (Sedwick-Rafter cell and Whipple disk). Table on characteristics of sampling instruments.

APHA Committee on Air Pollution - Review and Discussion of Methods of Analyzing Industrial Dusts (Pt. III Report of Sub-Committee on Dust Procedures in Air Analysis) AJPH Yearbook 1937-1938 pp. 86-90
(Supp. to Vol. 28, No. 2, Feb. 1938)

Abs. Size range is of importance in industrial dusts. Fractionation by water elutriation is used, each fraction analyzed. Chemical, X-ray diffraction and spectroscopic, and petrographic methods all used.
Proposed standard: (1) Collection of sample (a) Settled dust - easy; not always representative. (b) Air samples - Dust counting apparatus or small vacuum cleaner arrangement, (c) Raw materials - easy; helps in dust analysis. Fractionation: Dry, screen thru 270 mesh, separate fines by settling in water ($<0.5\mu$; $0.5-2\mu$; $2-5\mu$; $5-10\mu$)

APHA Committee on Standard Methods for Examination of Air. Sub-committee on Chemical Methods in Air Analysis. Sampling and Sampling Devices (Report) AJPH Yearbook 1939-1940. Supp. to Vol. 30, No. 2,Feb.1940,pp 92-97
(Goldman, Coleman, Elkins, Schrenk, Smucker)

Abs. Sampling locations - (1) Immediate vicinity of worker. (2) Near source of contaminant (3) General workroom. Devices: I. Indicating or Recording Instruments A - Direct Reading Scale Instruments. 1. CO Indicator MSA 2. Combustible Gas Indicator MSA 3. Benzol Indicator MSA 4. Interferometer for substances of high molecular refraction and relatively low toxicity.
B-1. British Test Paper Methods (a) H_2S (b) HCN (c) SO_2 (d) Benzene fumes (e) Nitrous fumes 2. Mercury Vapor Detectors (a) Nordlander (b) Lamp shade 3. H_2S Detector MSA 4.HCN Detector MSA 5. Hoolamite CO Detector MSA.

II. Devices which actually collect samples 1. Gas washing bottles (Drechsel, Allihn, Friedrich, Milligan, etc. types - for gases and vapors which are soluble or react rapidly with reagent employed). 2. Electric Precipitator MSA - Good for lead dust and fumes. Rate 3 cfm. 3. Greenburg-Smith Impinger - Standard for dusts, widely used for fumes and mists. Rate 1 cfm. (low efficiency on lead) 4. Midget Impinger - Dust only. Rate 3 l./min. 5. Fritted glass bubblers - For gases and vapors which are soluble or react with reagents. Rates 1/2-10 l./min. 6. Petri tubes - bubbler without fritted glass. Usually need several in series - for gases. 7. Multiple absorbers. 8. Glass beads or pearl columns - Useful with concentrated reagents or viscous liquids. 9. "Lift Pump" Absorber - Similar to air lift pump. Rate 1 cfm. Used for SO_2 and Cl_2. 10. Solid Adsorbents - Activated charcoal for organic vapors. II. Condensation Methods - Dry ice, liquid air, liquid N_2 - for NO_2, Hg vapor. Rate < 1 l./min. 12. Combustion Apparatus - halogenated hydrocarbons. 13. Sample bottles - Air grab sample.

APHA Committee on Air Pollution - APHA - Report on Air Pollution (Engineering Section) H.A. Whittaker, Chmn.; John Buxell; G.M. Fair, B.H. Jennings; Sol Pincus. AJPH - V 38, No. 6, June, 1948 pp. 761-769.

Abs.- Atmospheric air pollution only considered: smoke, dust, pollen, irritants, odors, gases, fumes, vapors, mists, radioactive substances. One can always stop a smoking stack. Difficult to demonstrate actual damage to health by smoke.
Irritants: SO_2, Cl_2, phosgene, acrolein, butadiene, H_2S.

Odors: Sulfides, disulfides, mercaptans, thiocyanates, iso-cyanides, similar compounds of tellurium and selenium, aldehydes. (concentrations of 0.1 ppm to as low as 0.0000001 p.p.m.)
Sampling: Dust and bacteria - electrostatic and thermal precipitators; filters; atomizers.
Smoke: Ringelmann charts; radioactive salts; conospheres.
Pollen: Cannot use Stokes Law - employ unit area method.
Odors: Difficult to measure; osmometry (threshold odor)
Control: Scrubbing and absorption towers; dust and fume collectors; Chemical processes.

Anderson, F.P.; Armspach, O.W. - A New Method of Making Air Dust Determinations J. Amer. Soc. Heat & Vent. Eng. 28 July 1922

Andrews, H.L.; Peterson, Dorothy C. - A Study of the Efficiency of Methods for Obtaining Vapor Samples in Air J. Ind. Hyg. & Tox. 29:403-407 Nov. 1947

Abs. - In chambers, samples rarely tally with amount being introduced because: (1) Vapor may be absorbed on walls; (2) Sampling may not be representative; (3) Analytical procedure may be cumbersome or inaccurate. Experiments with benzene and zylidine were run using Beckman Quartz Spectrophotometer.
Samplers used: (1) Evacuated Shephard flask, (2) Evacuated gas sampling flasks with vacuum pump operating for 3 min. (3) Two all-glass midget impingers in series, rate 0.2 l./min. Iso-octane used to dissolve vapors. Results were same ± 4% (midget impinger best at low concentration) Impinger preferred for xylidine.

Bloomfield, J.J.; Dalla Valle, J.M. - The Determination and Control of Industrial Dust PH Bull. 217 Apr. 1935 (Printed 1938) 167 pp.

Chapter - 1. Preliminary steps: The Sanitary and Occupational Survey; 2. The Instruments and Methods Used in the Sampling of Atmospheric Industrial Dusts; 3. The Quantification of Industrial Dusts; 4. The Determination of Character and Composition of Industrial Dusts; 5. Application of Dust Determinations to Practical Problems; 6. General Dust Control Measures; 7. Design of Hoods; 8. Design of Local Exhaust Systems; 9. Exhaust Ventilation in Practice; 10. Dust Collection and Disposal; 11. Measurement of Air Flow; 12. Personal Respiratory Protection; 13. Bibliography.

Brown, C.E., - Quant. Measurements of the Inhalation, Retention and Exhalation of Dusts and Fumes by Man. II. Concentrations Below 50 mg./Cu.M. and III Factors Involved in the Retention of Dusts and Fumes by Man J. Ind.Hyg. 13:8 Oct. 1931 and 13:9 Nov. 1931

Cummings, Donald E. - Studies on Experimental Pneumoconiosis IV. The Separation of Particulate Matter Smaller than Screen Sizes Into Graded Fractions J. Ind. Hyg. 11:245-256, 1929

Drinker, P.; Thomson, R.M.; Finn, J.L. - Quantitative Measurements of the Inhalation, Retention, and Exhalation of Dusts and Fumes by Man, I. Concentrations of 50 to 450 mg. per cu. M. J. Ind. Hyg. 10:1 Jan. 1928

Drinker, P. - Alternating Current Precipitators for Sanitary Air Analysis I. An Inexpensive Precipitator Unit J. Ind. Hyg. 14 p 364 1932

Greenburg, Leonard; Bloomfield, N.J. - The Impinger Dust Sampling Apparatus as Used by the U.S.P.H.S. PHR 47: 12 Mar. 18, 1932

Hatch, T.; Warren, H.; Drinker, P. - Modified Form of the Greenburg - Smith Impinger for Field Use, with a Study of its Operating Characteristics - J. Ind. Hyg. 14:8 Oct. 1932

Ives, James E.; Britten, R.H.; Armstrong, D.W.; Gill, W.A.; Goldman, F.H. - Atmospheric Pollution of American Cities for the Years 1931 to 1933 PHS Bull. No. 224, Wash., D.C., Gov't. Printing Office, (Mar. 1936) 75 pp.

Abs. - 14 cities grouped into I, II & III for presentation of data. Instruments - Owens automatic air filter (shade comparison); Owens jet dust counter; Smith-Greenburg Impinger; Settled dust collection (bottle and 30 cm funnel); Aitkin nuclei counter; Rentschler ultra violet meter, sling psychrometer, barometer, wind direction and cloudiness (from weather bureau).

Average of all results (winter):-

Mg. susp. matter/10 cu.m. air (impinger)				5.1
Carbon	"	"	"	3.3
Ash	"	"	"	1.8
Avg. shade no. (automatic filter)				1.3
No. particles/c.c. (jet dust counter)				815
No. condensation nuclei (Aitkin)/cc				207,000

Katz, S.H.; Smith, G.M.; Myers, W.M.; Trostel, T.J.; Ingels, Margaret; Greenburg, Leonard - Comparative Tests of Instruments for Determining Atmospheric Dusts P.H. Bull. 144 (Jan. 1925) 69 pp.

Abs. - Comparisons of: Sugar tube; Palmer apparatus, Kotze konimeter; paper thimble filter; Anderson-Armspatch dust determinator; Greenburg-Smith Impinger.

Impinger was developed during experiments. Using Palmer results as unity:
(1) By number of particles: Impinger = 5.0; sugar tube = 2.1
(2) By weight of dust: impinger = 2.1; Thimble = 1.5; Sugar tube = 1.6.

McCormick, W.E. - A Two-Cavity Dust Counting Cell Repr. 2621 from PHR 60:489-491 May 4, 1945

Abs. - In counting dust particles, 2 separate cells are plated from each sample of air. Time required to clean and set them up is objectionable. A 2-cavity cell is designed to reduce time. (Modified Dunn Cell) Original Dunn has 3 parts - (1) pyrex glass base, (2) a glass spacer 1.0 mm thick with 20 mm diameter hole, (3) cover glass. Use 3"x1½" microscope slide for base; use regular spacers (2); use either standard microscope cover glasses (No. 2 - 1"x1") or 2 made from a Sedgwick-Rafter cell cover glass.

Owens, J.S. - Jet Dust Counting Apparatus J. Ind. Hyg. 4:12 Apr. 1923

Seifert, H.E.; Keenan, R.G.; Fairhall, L.T. - A Procedure for the Handling of Field Samples of Dust and Fume. Repr. No. 2618 from PHR 60;441-443 Apr. 20, 1945

Abs. - Transfer of material from MSA electrostatic precipitator is often difficult and unsatisfactory as: (1) Amount of material is small (2) Reagents generally not of sufficient purity (3) Danger of contamination in field is great (4) Takes time to transfer (5) Breakage of glass shipping bottles. Use precipitator tube itself as shipping container. Make close-fitting plastic caps to close ends. Place in regular mailing tube. Tubes are weighed or material transferred in central laboratory. [Ed. note: Nothing said about any material which may be on the other electrode.]

Silverman, L.; Williams, C.R. - An Apparatus for Rapid Sampling of Large Air Volumes for Industrial Air Analyses J. Ind. Hyg. & Tox. 28:21-24 Jan.1946

Abs. - Regarding sampling for radium dusts, a sampler was developed with collection rate of 45-50 cfm. Filter paper method. Apparatus consists of: metering orifice (flowmeter, manometer and flow regulating valve), flexible hose, filter paper, a paper support, centrifugal vacuum blower. Pinch-type valve; flow meter of lucite with kerosene as liquid. Screen support for filter is cone and frustrum of cone, area 1.55 sq. ft. (Bases are 4.8" and 5.3" diameter x 10" height. [Ed. note: This is undoubtedly a made-over vacuum cleaner outfit.]

Trostel, L.J.; Frevert, H.W. - Collection and Examination of Explosive Dust in Air Ind. & Eng. Chem. V.15: No.3 Mar. 1923.

12. CONTROL OF AIR-BORNE POLLENS AND BACTERIA INDOORS

Dallavalle, J.M.; Hollaender, Alexander - The Effectiveness of Certain Types of Commercial Air Filters Against Bacteria (B.Subtilis) PHR 54:17 695-699 (Apr. 28,1939) Reprint from PHR #2063

Abs. - B. Subtilis (Ave. size = 2μ) used to test air filters. Equipment - Elutriator, filter adapter, orifice for gaging flow, regulating damper, constant feed blower fan, capacity - 2000 cfm. Bacteria introduced with ordinary spray gun at 10 psi. Sampled air at two points through tubes by means of impinger motors, 1 cfm, into funnel device with petri dish containing agar (Hollaender). Ran for 3 min. each and incubated 48 hrs. at 37°C. Types tested: Felt cloth, X-ply paper with oil; Y-ply paper with oil, Viscous impinging paper with grease; Steel wool (3" thickness) with germicidal oil; glass wool with oil; glass fabric; animal hair. Efficiencies were close and ranged from 32.6% (glass fabric) to 85.4% (steel wool).

Dautrebande, L.; Highman, B.; Alford, W.C. - Studies on Aerosols I. Reduction of Dust Deposition in Lungs of Rabbits by Aqueous Aerosols

J. Ind. Hyg. & Tox. 30:103-107 Mar. 1948.

Abs. - Coating particles of willemite dust with aerosols thought to reduce respiratory trouble in rabbits. Smaller amounts of dust were found in lungs when aerosols used. Due to (1) Particle size increase by coating and agglutination (2) Greater respiration rate favors deposition of particles before reaching lungs; (3) greater exudate in rabbits not exposed to aerosols favors entrapment and retention of more particles in lungs. Aerosols greatly reduced dust deposits in alveolar ducts and alveoli. Willemite readily identified by brilliant green fluorescence under ultra-violet radiation.

Dautrebande, L.: Alford, W.C.; Highman, C. - Studies on Aerosols. II. Coating and Agglutinating of Dust Particles by Aqueous Aerosols J. Ind. Hyg. & Tox. 30:108-113 Mar. 1948

Abs. - Generated dusts (quartz or willemite); aerosols. Sampled on glass slides coated with vaseline exposed 10 cm from ceiling for 1 hr. Particles less than 1μ can be coated and agglutinated to greater than 3μ and occasionally even 20μ diameter by aerosols. Aerosol used was from distilled water or aqueous solution of eosin Y at 45 cc/hr., flow at 50 l./min. Mean diameter of dust was less than 1μ (dry).
Conclusions: Aerosols may be useful in drilling and other dust-producing operations; Wet drilling, grinding, etc. does not do much good (water spray).

Dautrebande, L.; Highman, B.; Alford, W.C.; Weaver, F.L. - Studies on Aerosols III. Production of Liquid Aerosols with an Ave. Mean Micellary Diam. Under 1/2 μ . Study of the Agglutination of Liquid Micellae Archives Internationales de Pharmacodynamie et de Therapie LXXVI No. 3 May 1, 1948 pp 247 - 273

Abs. - Micellae are minute particles of water or aqueous solutions; Aerosol is dispersion of micellae in air or any gas. Study was designed to generate aerosols without large and unstable micellae but with stable ones. Passing aerosol from generator through a 2-liter impinger flask and bubbling stream through a layer of water in the flask improved results. Using more liquid barriers also helped. Got same size in solutions of 0.1 to 23%. Volume of dispersed solution equaled 10,000 - 11,000 cu. μ per cu. mm. of aerosol. Number visible at 1125X increases with dilution from 170,000 at 10% to 400,000 at 1%.

Drinker, P.; Wells, W.F. - A Method of Testing Filters Against Pollens, Bacteria and Molds Heat., Piping & Air Cond. - 6:408-410 Sept. 1934

Hamburger, M. Jr.; Robertson, O.H.; Puck, T.T. - The Present Status of Glycol Vapors in Air Sterilization Extracted from: A.J. Med. Sci. 209:162-166, Feb. 1945.

Abs. - Review of Literature: Laboratory investigations - 1941 (Robertson) glycol vapors effective against many organisms. Triethylene glycol effective in about 1/50 concentration as propylene glycol. Field tests - Harris & Stokes got 100 infections in control against 5 where propylene glycol was used in wards. Plate counts reduced 71% with propylene glycol and 97% with tri-ethylene. Commission on Air-borne Infection tested glycol on hemolytic streptococci and found 65% reduction, but in conjunction with oil treatment of bedclothing, found greater than 90%. Relative Humidity - best 35-50% (at 75° air can't hold enough vapor); Temperature - Low, best below 72° F.; dust and lint control helps appreciably. Four types of vaporizers - (1) From hot surface as radio resistor, soldering iron, light bulb. Then disperse with fans. Have to hold below 260°C. (2) Air passage over evaporating surfaces - heated air over evaporating dishes. (3) Boiling water-glycol mixtures. (4) Atomization of glycol-water solution - nozzles spray into air stream, baffles provided. Relative humidity - increased by steam or boiling, as in (3). Regulation of glycol content - keep just below saturation with regulating device (Puck). Toxicity and inflammability - glycol not very toxic, no fire or explosion hazard. Glycol does not harm fabrics; propylene glycol will attack varnishes but tri-ethylene glycol apparently doesn't. Glycol also effective against virus.

Harris, T.N.; Stokes, Jos. - Summary of a 3-Yr. Study of the Clinical Applications of the Disinfection of Air by Glycol Vapors Extracted from: A. Jour. Med. Sci. 209-152-156 Feb. 1945.

Abs. - Studies at Childrens Seashore Hosp., Atlantic City. Used propylene glycol 1941-1943 and tri-ethylene glycol 1943-1944. Vaporized by electrical resistance coil and blown by small electric fan. Petri dishes at 30-60 min. exposure.
Infection lower in wards containing vapor than in control (respiratory - 13 against 132). Concentration of propylene glycol - 0.069 mg/l. (.048 - .094); Tri-ethylene glycol - .0018 mg/l. to .0033 mg/l. Plate counts 4-6 times higher in control air.

Hollaender, A.; duBuy, H.G.; Ingraham, H.S.; Wheeler, S.M. - Control of Airborne Microorganisms by Ultraviolet Floor Irradiation Science, 99:130-131 Feb. 11, 1944.

Abs. - Bacteria in air correlate with human activity and are greatest at lower levels. Bacteria closely associated with dust on floors, lint on blankets. Irradiation of floor area may be better than irradiation of upper 1/3. Experiments in sheet-metal covered room - 9' x 7' x 8', floor irratiated with 4 - 8W lamps 30" above. Introduced house dust 1/2 hr. before experiment, kept 2 small fans going. Bacteria sampled with open plate, bubbler pump, funnel device - 4 sets of samples at 30 min. intervals and a control sample. Results showed 50-75% reduction after lights on, compared to none to 17% reduction in control. (Some floors may reflect rays too much).

Miller, W.R.; Jarrett, E.T.; Willmon, T.L., Hollaender, A.; Brown, E.W.; Lewandowski, T.; Stone, R.S. - Evaluation of Ultraviolet Radiation and Dust Control Measures in Control of Respiratory Disease at a Naval Training Center J. Infect. Dis. 82:86-100 Jan. - Feb., 1948

Abs. - Experiments in (1) Untreated (2) Irradiated and (3) Oiled buildings. Exposed (1) open agar plates; (2) bubbler tubes, 45 l. of air through 20 ml. broth and plated in crystal violet rabbit blood agar; (3) plated (agar) floor dust; (4) throat cultures of all men for streptococcus. Plates incubated at 37°C for 48 hrs. Results: Ultraviolet radiation of floors and upper air reduced respiratory diseases by 19.2% streptococcal diseases by 24%. No reduction in overall respiratory diseases by dust control with oil.

Schneiter, R. et al - Effectiveness of Ultra-violet Irradiation of Upper Air for the Control of Bacterial Air Contamination in Sleeping Quarters. Preliminary Report. Am. J. Hyg. 40:136-153 (Sept. 1944)

Abs. - Experiments in four dormitories; fourteen 30W. lights per dormitory. Bacterial studies (2 irradiated; 2 control) once a month, checked against nasal swab cultures. Maltose agar substituted for tryptose agar because of spreaders. Samplers: Wells centrifuge used initially but discontinued due to spreaders; Bottle sampler at 0.85 cfm; Petri plate at 5 and 3 min. Floor dust analyzed in water with serial dilutions in maltose blood agar. Counts not too significantly different. Bottle sampler not too good. Hospital admission rates about same and were higher than in 3 others not studied. Got streptococci and staphylococci predominately. Conclude irradiation of upper air gave some reduction in counts but can draw no conclusions.

Wells, Mildred W. & Wells, W. F. - Measurement of Sanitary Ventilation AJPH - 28:343-350 Mar. 1938

Abs. - Discussion of public health significance of bacteria in air. Need for purifying air and measuring efficiency. Sanitary Ventilation - rate at which microorganisms are vented; or proportional air replacement to remove equivalent numbers of microorganisms. Atomizer used to throw diluted culture of test organisms into air. Determined concentration by centrifuge (B. coli on EMB).

I. Die-away - Number of organisms removed in small time is proportional to number present, or $dN = -KN\,dt$; $\text{Log}_e \frac{N}{No} = -Kt$ and $N = No\,e^{-kt}$

Therefore: Number of overturns/hr. $= \frac{138 \times \text{Log}_{10} \frac{N}{No}}{t\ (\text{min})}$ $(138 = 60 \times 2.3)$

II. Equilibrium - Add bacteria at uniform rate until number withdrawn equals number introduced.

Concentration of organisms present $= \frac{C}{K}$ (C = addition rate) (K = removal rate - given by die-away)

Then changing a ventilating factor will result in new equilibrium. Can then compare equilibria.

Number after any time $= P = \frac{C}{K}\left(1 - e^{-Kt}\right)$

Bacterial Ventilation (?) by Ultraviolet Irradiation:

A. Irradiation of Recirculated Air - Usually impractical because it requires too many turnovers per hr.

B. Direct Irradiation of Room Air - Satisfactory if eyes of occupant can be protected. Ratio of equilibrium counts with lights on and lights off measures efficiency.

C. Partial Irradiation - Upper portion only (above eye level). Depends on air movement through irradiated space as well as spatial

distribution of radiation.
D. Light Barriers - Ultraviolet light screens around cubicles.

Wells, W. F. - Bactericidal Irradiation of Air I. Physical Factors J. Franklin Inst. - 229:347-372 Mar. 1940

Abs. - Lethal quality of different wave lengths is ergs/mm^2 per lethe. A lethe of exposure to a quartz mercury Geissler tube (90-95% in the 2537 Å line) corresponds to 3-4 ergs. per mm^2. Relative lethal quality of the different wave lengths in air and in water is of a similar order of magnitude. (organisms in dry air are about 20x as vulnerable to a given wave length as when suspended in water) (values in dry air are reduced 10x in humid air) (Many formulae are given)

Wells, W. F. - Ray Length in Sanitary Ventilation by Bactericidal Irradiation of Air - Jour. Franklin Institute 238:185-193 Sept. 1944

Concl. - The lengths of bactericidal rays may contribute four ways to sanitary ventilation:
(1) Amount of irradiation depends directly on mean ray length.
(2) Uniformity of irradiation normally increases with mean ray length.
(3) Uniformity of exposure depending on air circulation usually increases as rays are lengthened.
(4) Disinfection of organisms from occupant to occupant generally approaches average disinfection as rays are lengthened. The hygienic rating thus increases with ray length.

Wells, W. F. - Sanitary Ventilation by Radiant Disinfection Scientific Monthly - LX: 325-334 May, 1945

Abs. - This is a long discussion attempting to sell the reader on the need for disinfection of indoor air in certain places and the advantages of doing so with ultraviolet light. Claims vulnerability of organisms is more uniform to lethal radiation than to chemicals or heat treatment (with E. coli = 1.00; range is 0.22 for B. subtilis (spore) to 2.14 for bacteriophage).

Wells, W. F. - Circulation in Sanitary Ventilation by Bactericidal Irradiation of Air J. Franklin Inst. - 240:379-396 Nov. 1945.

Abs. - Lethe is sanitary equivalent of an air change of ventilation. Lethal exposure of E. coli atomized into dry air at 2537 Å revaluated. Exposure to 0.002 watt-min./ft^2 or 0.002 watt-min/cu.ft. of uniform irradiation gives 1.0 lethe of disinfection.
Recirculated air must be exposed to at least 5X the direct irradiation in a room to provide the approximate sanitary equivalent of fresh air. Sanitary equivalent of 1,000 cfm obtained by 6 ft.-watts of irradiation per pupil.

Wheeler, S. M.; Ingraham, H. S.; Hollaender, A.; Lill, N. D.; Gershon - Cohen, J.; Brown, E. W. - Ultra-violet Light Control of Air-borne Infections in a Naval Training Center AJPH - 35:457-468 May, 1945

Abs. - Four groups of 11 companies (112 men each) were each tested. Two were controls, one had high intensity ceiling and floor lamps and one had low intensity ceiling and floor lamps in barracks only. Card record on each man. Rates/1000: High intensity (235 watts) - 90.4; Control - 114.3; Low intensity (121 watts) - 103.6; Control - 98.1. (All respiratory admissions). Better reduction in Dec. and Jan. (Experiments ran Dec. 15 - May 31). Conclude that 25% reduction in high intensity obtained. Bacterial counts were 50% or more less than controls.